# OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
# DESIGN CALCULATION OR ANALYSIS COVER SHEET

1. QA: QA
2. Page 1

| 3. System: | 4. Document Identifier: | 5. Verified: |
|---|---|---|
| Uncanistered Spent Nuclear Fuel | 000-00C-DSU0-00700-000-00A | ☐ Yes ☒ No |

6. Title:
Gamma and Neutron Radiolysis in the 21-PWR Waste Package from Ten to One Million Years

7. Group:
Special Analyses & Waste Package Design

8. Document Stabs Designation:
☐ Preliminary ☐ Final ☒ Superseded ☐ Cancelled

9.

| T | F | |
|---|---|---|
| ☒ | ☐ | 1. This product contains no potentially sensitive information. |
| ☐ | ☒ | 2. This product contains information that could definea target. |
| ☐ | ☒ | 3. This product contains information that could define a specific W a n . |
| ☐ | ☒ | 4. This product contains information that identifies vulnerabilities. |

10. Notes/Comments:

| | Total Number of Pages |
|---|---|
| I | 2 |
| II | |
| III (one compact disk) | 0 |
| | |

## RECORD OF REVISIONS

| 11. No. | 12. Reason for Revision | 13. Total No. of Pages | 14. Last Page No. | 15. Originator (Print/Sign) | 16. Checker (Print/Sign) | 17. Quality Engineering Representative (Print/Sign) | 18. Approved/ Accepted (Print/Sign) | 19. Date |
|---|---|---|---|---|---|---|---|---|
| REV A | This document supersedes CAL-MGR-NU-000006 REVOO, and is an extensive revision of the previous calculation because the time period has been expanded fiom 10 years to one million years. the energy depositions are tallied directly instead of deriving fiom 1.1-1977 dose factors. Corrected per CR-3588 FTH 10-12-04 | 49 | II-1 | Jabo S. Tang SIGNATURE ON FILE 9/18/2002 10/18/2004 | Georgeta Radulescu SIGNATURE ON FILE 9/18/2002 GR 10/8/2004 | Dan Tunney SIGNATURE ON FILE 9/18/2002 | N/A 10/12/04 | N/A |

## CONTENTS

## FIGURES

**Page**

## TABLES

**Page**

## 1. PURPOSE

The purpose of this calculation is to determine the radiolytic production of nitric acid and other chemical species by gamma and neutron radiation inside the 21-PWR (pressurized-water reactor) waste package (WP). The scope of this calculation is for the spent nuclear fuel (SNF) decay time period between ten to one million years.

The results of this calculation will be used to evaluate nitric acid corrosion of fuel cladding from radiolysis in the 21-PWR WP. The 21-PWR WP is a part of the Monitored Geologic Repository (MGR) Uncanistered SNF Disposal Container System. The MGR Uncanistered SNF Disposal Container System is classified as Quality Level 1 (CRWMS M&O [Civilian Radioactive Waste Management and Operator Contractor] 1999a, page 7). Therefore, this calculation is subject to the requirements of the Quality Assurance Requirements and Description (DOE [U.S. Department of Energy 2002). The performance of the calculation and development of this document are carried out in accordance with AP-3.12Q, *Design Calculations and Analyses.* This calculation is associated with the total system performance assessment (TSPA) of which the integrity of the spent fuel cladding is to be evaluated.

The calculation method, input description, and results from this calculation are given in the following sections. The information provided by the sketch attached to this calculation is that of the potential design for the type of WP considered in this calculation.

## 2. METHOD

The integrity of the cladding material of PWR SNF is one of the issues of the TSPA for the site recommendation (SR) study. It is recognized that chemical species produced by ionizing radiation (radiolysis) can have deleterious effect on the fuel cladding by nitric acid corrosion. Nitric acid is produced in an irradiated air-water vapor system when the hydroxyl radicals, generated from water vapor, convert nitrogen dioxides, formed by radiolytic reaction between nitrogen and oxygen, to nitric acids. Prior to waste package failure, radiolysis effect is insignificant because of the absence of water and air in the waste package. Therefore, it is only after waste package failure that radiation-enhanced corrosion of fuel cladding can occur. For this calculation the 21-PWR WP is assumed to have failed and air and water have entered the WP (Assumption 3.1).

Although radiolytic production of individual chemical species depends on the radiation environment, the chemical components present, and the physical conditions of the environment (temperature, pressure, and relative humidity), the yield of a chemical species is characterized by a single parameter, G value (Reed and Van Konyneburg, 1991). The G value represents the number of molecules of a chemical species produced per 100 eV of radiation energy absorbed in the ambient environment; it has the dimensions of (molecules/100 eV).

In this calculation, it is assumed that the 21-PWR WP has been breached, and air and water are present inside the WP (Assumption 3.1). For the failed waste package, the maximum amount of nitric acid production is determined by the total radiation energy absorbed by the moist air in the waste package. The 21-PWR WP is assumed to contain the average SNF (Assumption 3.2), and the energy deposition rates outside the fuel rods are calculated at 35 time steps within the time period between ten to one million years. Then, the rate of nitric acid production is determined for each time step based on the energy deposition and the G values of 1.5 for both neutron and gamma radiation (Assumptions 3.9 and 3.10). The average PWR SNF has the following characteristics: 4.0-wt% initial $^{235}U$, 48-GWd/MTU burnup, and 21-year decay time (Assumption 3.2).

Three-dimensional Monte Carlo calculations of the energy deposition rates and dose rates inside the 21-PWR WP are carried out using the MCNP program (Briesmeister 1997). The code collects information about events that occur during the random walks of particles in set of variables known as tallies. A series of these tallies have been specified in the MCNP input decks to obtain estimates for the energy deposition and particle flux in the moist air in the nine central assemblies. Information are collected for both gamma and neutron calculations using the "f6" and "f4" tallies that are defined as

- f6 energy deposition averaged over a cell in MeV/g
- f4 flux averaged average over a cell in particles/$cm^2$.

The f6 results are converted to nitric production rates using the G values, the moist air density, and the total volume of the moist air. The f4 results are converted to dose rates using the ANSI/ANS-6.1.1-1977 flux-to-dose-rate conversion factors (Briesmeister 1997, pages H-5 and H-6).

## 3. ASSUMPTIONS

3.1 It is assumed that the 21-PWR WP has failed and air and water are present in the WP. The rationale for this assumption is that air and water must be present for radiolysis to take place. This assumption is used in Section 5.

3.2 The PWR SNF having 4.0-wt% initial $^{235}U$, 48-GWd/MTU burnup, and 21-year decay time is assumed to be the SNF with average characteristics. The rationale for this assumption is that the source term for the SNF with these characteristics generates conservative (higher) radiation dose rates for an average PWR SNF (BSC [Bechtel SAIC Company] 2001, Assumption 3.3). This assumption is used in Section 5.

3.3 The chemical composition of the SNF is assumed to be the same as that of the fresh fuel. The rationale for this assumption is that small weight variations of the elements do not affect the accuracy of the gamma radiation energy absorption outside the SNF rods, as long as the total weight is maintained. Also, using fresh fuel for SNF results in conservative (higher) neutron energy absorption outside the SNF rods. This assumption is used in Section 5.

3.4 The non-fuel material compositions used in this calculation have elements with allowable ranges of weight percentages. For elements with weight percent range, the midpoint value is used, and the weight percent of the most abundant element is adjusted. The rationale for this assumption is that small weight variations for the affected elements do not affect the accuracy of dose results, as long as the total weight is maintained. This assumption is used throughout Section 5.

3.5 The basket assembly, the trunnion collar sleeves, the extended outer shell lid, the lifting features of the upper shell lids, and the bottom support ring in the 21-PWR WP are not represented in the geometry of the MCNP calculations. The rationale for this assumption is that excluding the basket assembly yields higher (conservative) radiation dose rate and the other components have negligible effects on the energy absorption in the WP. This assumption is used in Section 5.

3.6 For each PWR SNF assembly, the following items in the active fuel region are not included in the MCNP calculations: the guide tubes, instrument tube, incore-spacers, and grid supports. The rationale for this assumption is the same as that for Assumption 3.5. This assumption is used in Section 5.

3.7 For each PWR SNF assembly, the materials in the plenum region, top end-fitting region, and bottom end-fitting region are homogenized within the lateral boundaries of the assembly. The rationale for this assumption is that the reflective effects of these regions on energy deposition in the lattice cells are very small. Thus, homogenization of these regions should give the similar effect. This assumption is used in Section 5.

3.8 It is assumed that the internal configuration of the 21-PWR WP remains intact for the entire time period of one million years. The rationale for this assumption is that the intact configuration leads to higher (conservative) radiolytic production of chemical species due to higher dose rate in the moist air in the WP. This assumption is used in Section 5.5.

3.9 It is assumed that the G value for nitrogen dioxide (or nitric acid) production by gamma radiation is 1.5 molecules/100 eV. The rationale for this assumption is that the G values between 0.5 to 1.5 molecules/100 eV have been observed in the long-term and lower dose rate gamma studies (Reed and Van Konynenburg 1991, p. 1399). Since this calculation is for long-term and low gamma irradiation conditions, G value of 1.5 is conservative by producing the highest of nitric acid. This assumption is used in Section 5.5.

3.10 It is assumed that the G value for nitric acid production by neutron radiation is 1.5 molecules/100 eV. The rationale for this assumption is that the G value of 1.5 molecules/100 eV absorbed by the nitrogen component of the gas phase in a air-water system has been reported (Reed and Van Konynenburg 1988, p. 401). Since the G value used in this calculation is per 100 eV energy absorbed by all components, using the G value of 1.5 is conservative for of nitric acid production. This assumption is used in Section 5.5.

3.11 It is assumed that the pressure in the failed 21-PWR WP is one atmosphere and the temperature in the WP is between 30" C and 90" C with relative humidity between 40% to 90%. The rationale for this assumption is that the WP has failed and exposed to the atmosphere and the temperature and relative humidity ranges correspond to those of the measured G values for nitrate production (Figure 3, Reed and Van Konyneburg, 1991). This assumption is used in Sections 5 and 6.

3.12 It is assumed that neutron spectra for PWR SNF at different decay times are identical. The rationale for this assumption is that neutron source in the commercial SNF is dominated by neutrons from spontaneous fission of actinides. Since spontaneous fission spectra of actinides are similar, the neutron spectra at different decay times should be nearly the same. This assumption is supported by Figure 4, which depicts the neutron source spectra of the average PWR SNF for time from one year to one million years. This assumption is used in Sections 5 and 6.

# 4. USE OF COMPUTER SOFTWARE AND MODELS

## 4.1 COMPUTER SOFTWARE

### 4.1.1 MCNP 4B2LV

The MCNP 4B2LV computer code (CRWMS M&O 1998a) was used to calculate gamma and neutron energy absorption and fluxes inside the WP. The software was qualified according to Office of Civilian Radioactive Waste Management (OCRWM) procedure AP-SI.1Q, ***Software Management.*** The software specifications are as follows:

Program Name: MCNP
Version/revision number: Version 4B2
CSCI Number: 30033 V4B2LV (CRWMS M&O 1998a)

- Computer Type: Hewlett Packard (HP) 9000 Series Workstations
- Status/operating system: Qualified/HP-UX B.10.20
- Computer processing unit number: Installed on the CRWMS M&O workstation 'Bloom,' YMP Tag 700887.

The input and output files for the various MCNP calculations are contained on a compact disk-read only memory (CD-ROM) (Attachment III) with the files documented in Table 25. The calculation spreadsheets described in Sections 5 and 6 and included in Attachment III are such that an independent repetition of the calculations may be performed.

The MCNP software used was:

(a) appropriate for the calculation of radiation dose rate and radiant energy deposition (MCNP is a Monte Carlo computer program designed for shielding and criticality calculations and for tracking neutron and gamma radiation)

(b) used only within the range of validation (benchmark cases used in validation the code include a number of critical configurations involving $UO_2$ fuels and shielding configurations involving neutron and gamma particle transport (CRWMS M&O 1998b)

(c) obtained from the Software Configuration Management in accordance with appropriate procedures.

### 4.1.2 MICROSOFT EXCEL 97 SR-2

Title: Excel
Version/Revision Number: Microsoft® Excel 97 SR-2

- This software is installed on a personal computer running Microsoft Windows 95 with CRWMS M&O Tag number 116210.

Microsoft Excel for Windows, Version 97 SR-2, was used in this calculation to translate the input data into the correct format and units using standard mathematical expressions and operations. It was also used to reformulate and display results graphically or in tabular form. The user-defined formulas, inputs, and results are documented in sufficient detail to allow an independent repetition of computations. Thus, Microsoft Excel is used only as a worksheet and not as a software routine. Microsoft Excel is an exempt software product according to OCRWM procedure AP-SI.1Q, Section 2.1.1, *Software **Management.***

## 4.2 MODELS

Not used.

# 5. CALCULATION

This section provides the radiation source terms, the geometry of the 21-PWR WP, and the chemical compositions of the materials used in MCNP calculations. The WP consists of the 21-PWR disposal container, 21 PWR SNF assemblies, and a basket assembly. Sketch SK-0175 REV 02 that is included in Attachment I describes the geometry and material specifications of the 21-PWR disposal container used in this calculation. So long as the internal configuration of the assemblies and basket does not change, minor changes in container wall thickness or other external dimensions will have only a negligible effect on the results of this calculation.

The number of digits in the values cited herein may be the result of a calculation or may reflect the input from another source; consequently, the number of digits should not be interpreted as an indication of accuracy.

## 5.1 21-PWR DISPOSAL CONTAINER

The 21-PWR disposal container primary consists of an inner reinforcement cylindrical shell, an outer shell, top and bottom inner shell lids, a bottom outer-shell lid, two top outer shell lids, upper and lower trunnion collar sleeves, and the basket assembly. The details of geometry and material specifications of the 21-PWR disposal container are described in sketch SK-0175 REV 02. The basket assembly, the trunnion collar sleeves, the extended outer shell lid, the extended lid reinforcement ring, the lifting features of the upper shell lids, and the bottom support ring are not represented in the MCNP calculations (Assumption 3.5). Table 1 presents the geometry and material specifications of the 21-PWR disposal container that are represented in the MCNP calculations.

The chemical compositions and the associated atom densities of SB-575 N06022 and SA-240 S31600 are given in Tables 2 and 3, respectively. For elements with weight percent range, the midpoint value is used, and the weight percent of the most abundant element is adjusted (Assumption 3.4).

The atom densities (AD) of the element/isotope contents, in atoms/b-cm are calculated according to the following equation (Harmon et al. 1994, p. B-2):

$$\mathrm{AD}\ (atoms/b.\mathrm{cm}) = \frac{\text{material density}(g/cm^3) * \text{weight fraction}_{\text{isotope}} * \mathrm{N_A}(atoms/mole)}{10^{24}(\mathrm{b/cm^2}) * \text{atomic mass}_{\text{isotope}}(g/mole)} \qquad \text{(Eq.1)}$$

In the above equation, $N_A$ is the Avogadro constant, whose value is 6.0221367E+23 atoms per mole (Parrington et al. 1996, page 59).

Table 1. Geometry and Material Specifications for the 21-PWR Disposal Container

| Component | Material | Characteristic | Dimension (mm) |
|---|---|---|---|
| Inner shell | SA-240 S31600 | Thickness | 50 |
| Top and bottom Inner lids | SA-240 S31600 | Thickness | 95 |
| Outer shell | SB-575 N06022 | Thickness | 20 |
| Top and bottom outer lids | SB-575 N06022 | Thickness | 25 |

| | | | |
|---|---|---|---|
| Closure lid to outer lid gap | Void | Thickness | 30 |
| Closure lid | SB-575 N06022 | Thickness | 10 |
| Inner lid to closure lid gap | Void | Thickness | 30 |
| Bottom outer lid to inner lid gap | Void | Thickness | 70 |
| Fuel basket tube | SA-516 K02700[a] | Thickness | 5 |
| | | Inner transverse dimension | 226.4 |
| Cavity | Void | Length | 4,585 |
| | | Inner diameter | 1,424 |

NOTE: [a]Represented as void in MCNP calculations (Assumption 3.5).

Table 2. Chemical Composition of SB-575 N06022

| Element[a] | Weight Percent Range[a] | Weight Percent Used | Atomic Mass[b] (g/mole) | Atom Density (atoms/b•cm) |
|---|---|---|---|---|
| C | 0.015 (max) | 0.015 | 12.0107 | 6.5357E-05 |
| Mn | 0.50 (max) | 0.5 | 54.93805 | 4.7629E-04 |
| Si | 0.08 (max) | 0.08 | 28.0855 | 1.4907E-04 |
| Cr | 20.00-22.50 | 21.25 | 51.9961 | 2.1387E-02 |
| Mo | 12.5-14.5 | 13.5 | 95.94 | 7.3638E-03 |
| Co | 2.50 (max) | 2.5 | 58.9332 | 2.2200E-03 |
| W | 2.5-3.5 | 3 | 183.84 | 8.5399E-04 |
| V | 0.35 (max) | 0.35 | 50.9415 | 3.5956E-04 |
| Fe | 2.0-6.0 | 4 | 55.845 | 3.7484E-03 |
| P | 0.02 (max) | 0.02 | 30.97376 | 3.3791E-05 |
| S | 0.02 (max) | 0.02 | 32.066 | 3.2640E-05 |
| Ni | Balance | 54.765 | 58.6934 | 4.8830E-02 |
| Total | | 100 | | 8.6374E-02 |
| | | Density = 8.69 g/cm$^3$ | | |

SOURCE: [a]ASTM (American Society for Testing and Materials) B 575-97, Standard Specification for Low-Carbon *Nickel-Molybdenum-Chromium,* Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon *Nickel-*Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip, p. 2.
[b]Parrington et al. 1996.

Table 3. Chemical Composition of SA-240 S31600

| Element | Weight Percent Range[a] | Weight Percent Used | Atomic Mass[c] (g/mole) | Atom Density (atoms/b•cm) |
|---|---|---|---|---|
| Carbon | 0.08 (max) | 0.08 | 12.0107 | 3.2009E-04 |
| Mn | 2.00 (max) | 2 | 54.93805 | 1.7495E-03 |
| P | 0.045 (max) | 0.045 | 30.97376 | 6.9819E-05 |
| S | 0.030 (max) | 0.03 | 32.066 | 4.4960E-05 |
| Si | 0.75 (max) | 0.75 | 28.0855 | 1.2833E-03 |
| Cr | 16.00-18.00 | 17 | 51.9961 | 1.5712E-02 |
| Ni | 10.00-14.00 | 12 | 58.6934 | 9.8253E-03 |
| Mo | 2.00-3.00 | 2.5 | 95.94 | 1.2523E-03 |
| N | 0.10 (max) | 0.1 | 14.00674 | 3.4310E-04 |
| Fe | Balance | 65.495 | 55.845 | 5.6361E-02 |
| Total | | 100 | | 8.6961E-02 |
| | | Density = 7.98 g/cm$^3$ | | |

SOURCE: [a] ASTM A 240/A 240M-97a, Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels, p. 2.
[b] ASTM G 1-90, Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens, p. 7.
[c]Parrington et al. 1996.

## 5.2 PWR SNF ASSEMBLIES

The PWR SNF assembly used in this calculation is a Babcock and Wilcox (B&W) 15x15 PWR SNF assembly. The mechanical design parameters for a B&W 15x15 PWR fuel assembly are obtained from (BSC 2001, Table 7). Table 4 presents these parameters.

Fresh fuel is assumed for the PWR SNF (Assumption 3.3). To be consistent with the values used in the source term calculations, the mass of uranium and uranium dioxide for each assembly are obtained from CRWMS M&O (1999b, Attachment I, p. I-1) instead of using the values in Table 4. The composition of fresh fuel is presented in Table 5. The composition of Zircalloy-4 is given in Table 6. For elements with weight percent range, the midpoint value is used, and the weight percent of the most abundant element is adjusted (Assumption 3.4).

In MCNP calculations, each PWR SNF assembly axially consists of four regions: the bottom end-fitting region, active fuel region, plenum region, and top end-fitting region. Except for the active fuel region, each assembly region is homogenized inside its volume (see Figures 1 through 3), resulting in a uniform distribution of the region contents inside each region volume (Assumption 3.7). For the active fuel region, the content of each cell in the assembly is represented explicitly, but the guide tubes, instrument tube, incore-spacers, and grid supports are not included (Assumption 3.6). The chemical compositions and the associated atomic densities of the three non-fuel regions of each PWR assembly are obtained from BSC (2001, Attachment I) and presented in Tables 7, 8, and 9.

Table 4. Mechanical Design Parameters of B&W 15x15 Mark B Fuel Assembly[a]

| Design Component | Material | Zone | Characteristic | Value |
|---|---|---|---|---|
| Assembly | N/A (Not Applicable) | NIA | Width | 8.536 in. (21.68144 cm) |
| | | | Length | 165.625 in. (420.6875 cm) |
| Fuel pin | N/A | In core | Number per assembly | 208 |
| | | | Length | 153.68 in. (390.3472 cm) |
| Fuel pellets | $UO_2$ | Active fuel | Mass/pin | 5.58 lb. (2.53105 kg) |
| | | | Mass Ulassemblv | 0.46363 metric tons |
| | | | Diameter | 0.3686 in. (0.93624 cm) |
| | | | Stack length | 141.8 in. (360.172 cm) |
| Cladding | Zircaloy-4 | In core | Thickness | 0.0265 in. (0.06731 cm) |
| | | | Fuel-clad gap | 0.0042 in. (0.010668 cm) |
| Top nozzle | SS CF3M | Top | Masslassembly | 7.48 kg |
| Bottom nozzle | SS CF3M | Bottom | Mass/assembly | 8.16 kg |
| Guide tube | Zircaloy-4 | In core | Masslassembly | 8.0 kg |
| Instrument tube | Zircaloy-4 | In core | Mass/assemblv | 0.64 kg |
| Spacer-plenum | Inconel-718 | Plenum | Mass/assembly | 1.04 kg |
| Spacer-bottom | Inconel-718 | Bottom | Masslassembly | 1.3 kg |
| Spacer-incore | Inconel-718 | In core | Masslassembly | 4.9 kg |
| Spring retainer | SS CF3M | Top | Mass/assembly | 0.91 kg |
| Holding spring | Inconel-718 | Top | Mass/assembly | 1.8 kg |
| Upper end plug | SS 304 | Top | Mass/assembly | 0.06 kg |
| Upper nut | SS 304L | Top | Mass/assembly | 0.51 kg |
| Lower nut | SS 304 | Bottom | Mass/assembly | 0.15 kg |
| Grid supports | Zircaloy-4 | In core | Masslassembly | 0.64 kg |
| Plenum spring | SS 302 | Plenum | Masslassembly | 0.042 lb. (0.0 kg) |
| Plenum region | N/A | N/A | Length[b] | 30.1752 cm |

| | | | | |
|---|---|---|---|---|
| Bottom end-fitting | N/A | N/A | Length[c] | 4 in. (10.16 cm) |
| Fuel pin pitch | NIA | N/A | Width[d] | 1.44272 cm |

SOURCE: [a]BSC 2001, Table 7.
NOTES: [b]Calculated: fuel pin length – fuel pellet length = 390.3472 cm – 360.172 cm.
[c]A bottom end-fitting region of 4-in. length provides conservative (higher) dose rates for bottom region of the WP.
[d]Punatar 2001. Table 2-2.

Table 5. Chemical Composition of Fresh PWR Fuel

| Isotope | Isotopic Mass[a] (g/mole) | Wt% of U[b] | Wt. Portion of $UO_2$ | Wt. Fraction of $UO_2$ | Atom Densitv (atoms/b•cm) |
|---|---|---|---|---|---|
| U-235 | 235.043922 | 4.0000 | 0.0400 | 0.0352 | 9.4426E-04 |
| U-234 | 234.040945 | 0.0347 | 0.0003 | 0.0003 | 8.2334E-06 |
| U-236 | 236.045561 | 0.0184 | 0.0002 | 0.0002 | 4.3252E-06 |
| U-238 | 238.050785 | 95.9469 | 0.9595 | 0.8443 | 2.2364E-02 |
| O | 15.9994 | NIA | 0.1364 | 0.1200 | 4.7289E-02 |
| Total | N/A | N/A | 1.1364[c] | 1.0000 | 7.0609E-02 |
| Density[a] = 10.47 g/cm$^3$ | | | | | |

SOURCE: [a]Parrington et al. 1996.
[b]BSC 2001, Table 1-5.
[c]CRWMS M&O 1999b, Attachment I, p. I-1. Mass of $UO_2$/mass of U = 539.771475 = 1.1364.
[d]CRWMS M&O 1999b, Attachment I, p. I-1.

Table 6. Chemical Composition of Zircalloy-4

| Element | Weight Percent Range[a] | Weight Percent Used | Atomic Mass[c] (g/mole) | Atom Density (atoms/b•cm) |
|---|---|---|---|---|
| Sn | 1.20-1.70 | 1.45 | 118.71 | 4.8254E-04 |
| Fe | 0.18-0.24 | 0.21 | 55.845 | 1.4856E-04 |
| Cr | 0.07-0.13 | 0.115 | 51.9961 | 8.7374E-05 |
| O | 0.09-0.16 | 0.125 | 15.9994 | 3.0865E-04 |
| Fe + Cr | 0.28-0.37 | 0.325 | N/A | N/A |
| Zr | Balance | 98.1 | 91.224 | 4.2483E-02 |
| Total | N/A | 100 | N/A | 4.3510E-02 |
| Density[b] = 6.56 g/cm$^3$ | | | | |

SOURCE: [a]ASTM B 811-90, Standard Specification for Wrought Zirconium Alloy Seamless Tubes for Nuclear Reactor Fuel *Cladding,* Table 2.
[b]ASM International 1990, p. 666.
[c]Parrington et al. 1996.

Table 7. Chemical Composition of the Bottom End-Fitting Region[a]

| Element/Isotope | Mass (g) | Nuclide Identification[c] | Atomic Mass[b] (glmole) | Atom Density (atoms/b•cm) |
|---|---|---|---|---|
| C | 3.608 | 6000.01p | 12.0107 | 3.7877E-05 |
| Mn | 129.95 | 25055.01p | 54.93805 | 2.9825E-04 |
| P | 0.2625 | 15031.01~ | 30.97376 | 1.0686E-06 |
| S | 0.24 | 16000.01p | 32.066 | 9.4373E-07 |
| Si | 168.875 | 14000.01p | 28.0855 | 7.5817E-04 |
| Cr | 1825.9 | 24000.01p | 51.9961 | 4.4278E-03 |
| Ni | 1499.375 | 28000.01p | 58.6934 | 3.2211E-03 |

| | | | | |
|---|---|---|---|---|
| N | 0.15 | 7014.01p | 14.003074 | 1.3507E-06 |
| Fe | 5636.1865 | 26000.01p | 55.845 | 1.2725E-02 |
| Mo | 243.65 | 42000.01p | 95.94 | 3.2022E-04 |
| Nb | 66.625 | 41093.01p | 92.90638 | 9.0422E-05 |
| Ti | 11.7 | 22000.01p | 47.867 | 3.0820E-05 |
| Al | 6.5 | 13027.01p | 26.98154 | 3.0376E-05 |
| Co | 13 | 27059.01p | 58.9332 | 2.7814E-05 |
| Cu | 3.9 | 29000.01p | 63.546 | 7.7385E-06 |
| B | 0.078 | N/A | 10.811 | 9.0972E-07 |
| $^{10}$B (19.9 at%) | N/A | 5010.01p | N/A | 1.8103E-07 |
| $^{11}$B (80.1 at%) | N/A | 5011.01p | N/A | 7.2869E-07 |
| **Total** | 9610 | N/A | N/A | 2.1981E-02 |

SOURCE: [a]BSC 2001, Atttachment I, Table 1-3.
[b]Parrington et al. 1996.
[c]Briesmeister 1997, Appendix G.

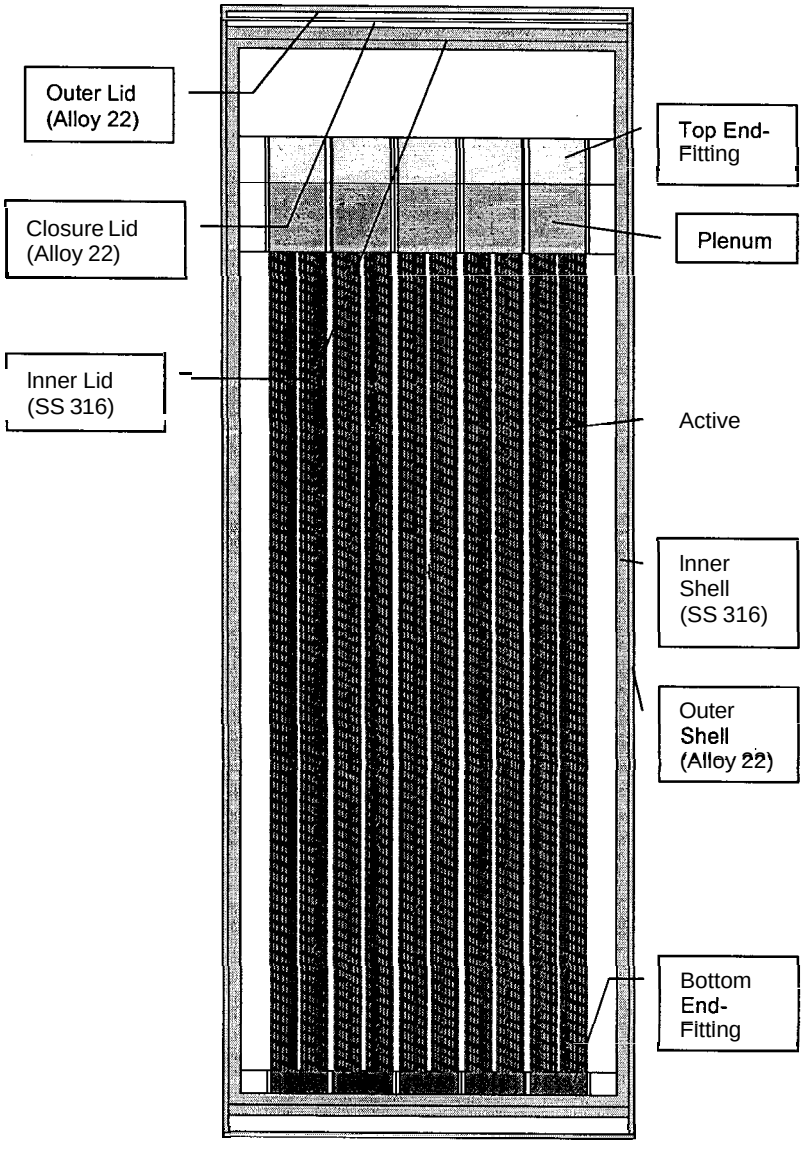



Figure 1. Source Region Representation in MCNP Calculations

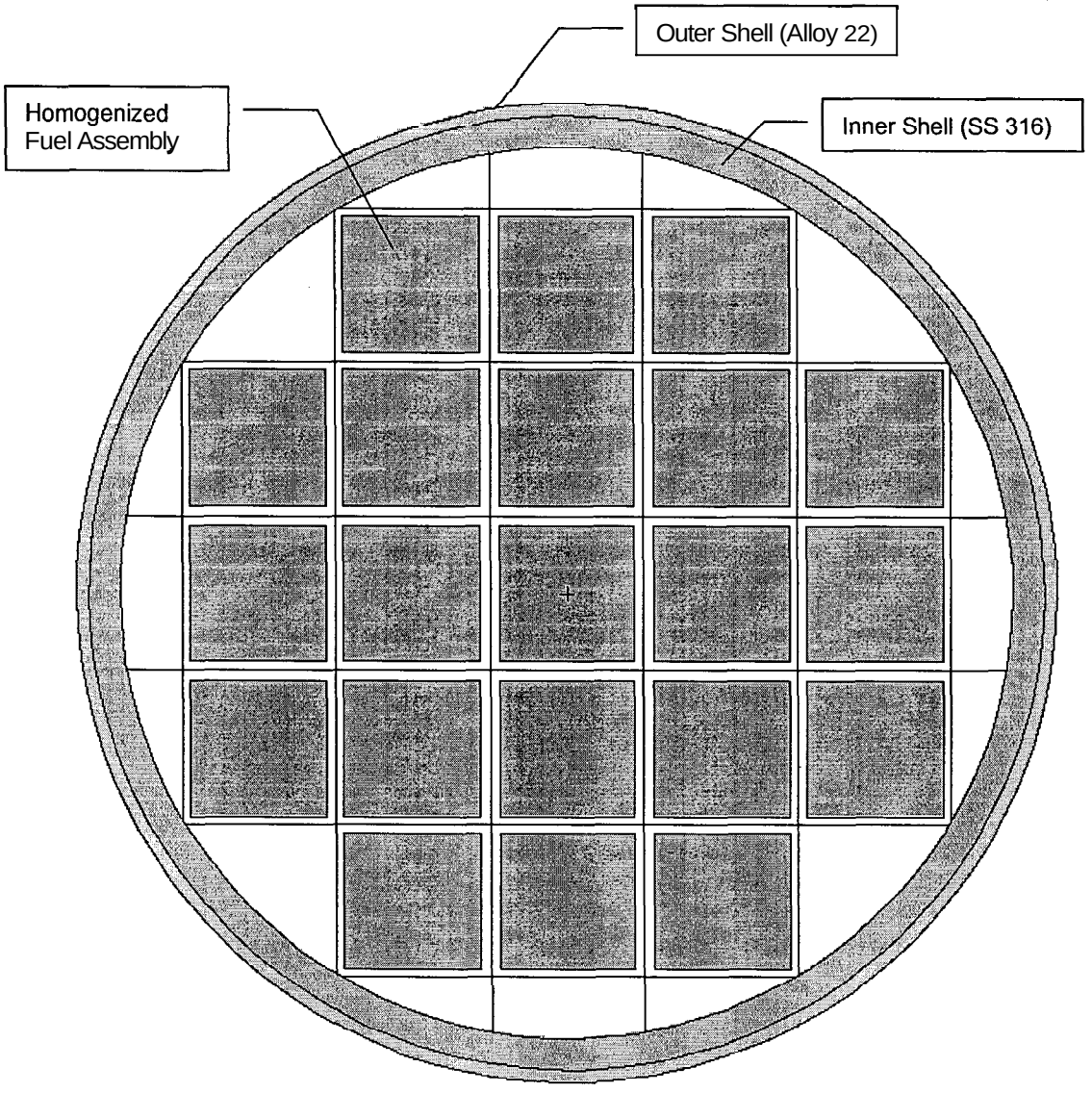



Figure 2. Lateral View of the WP Plenum Region in MCNP Calculations

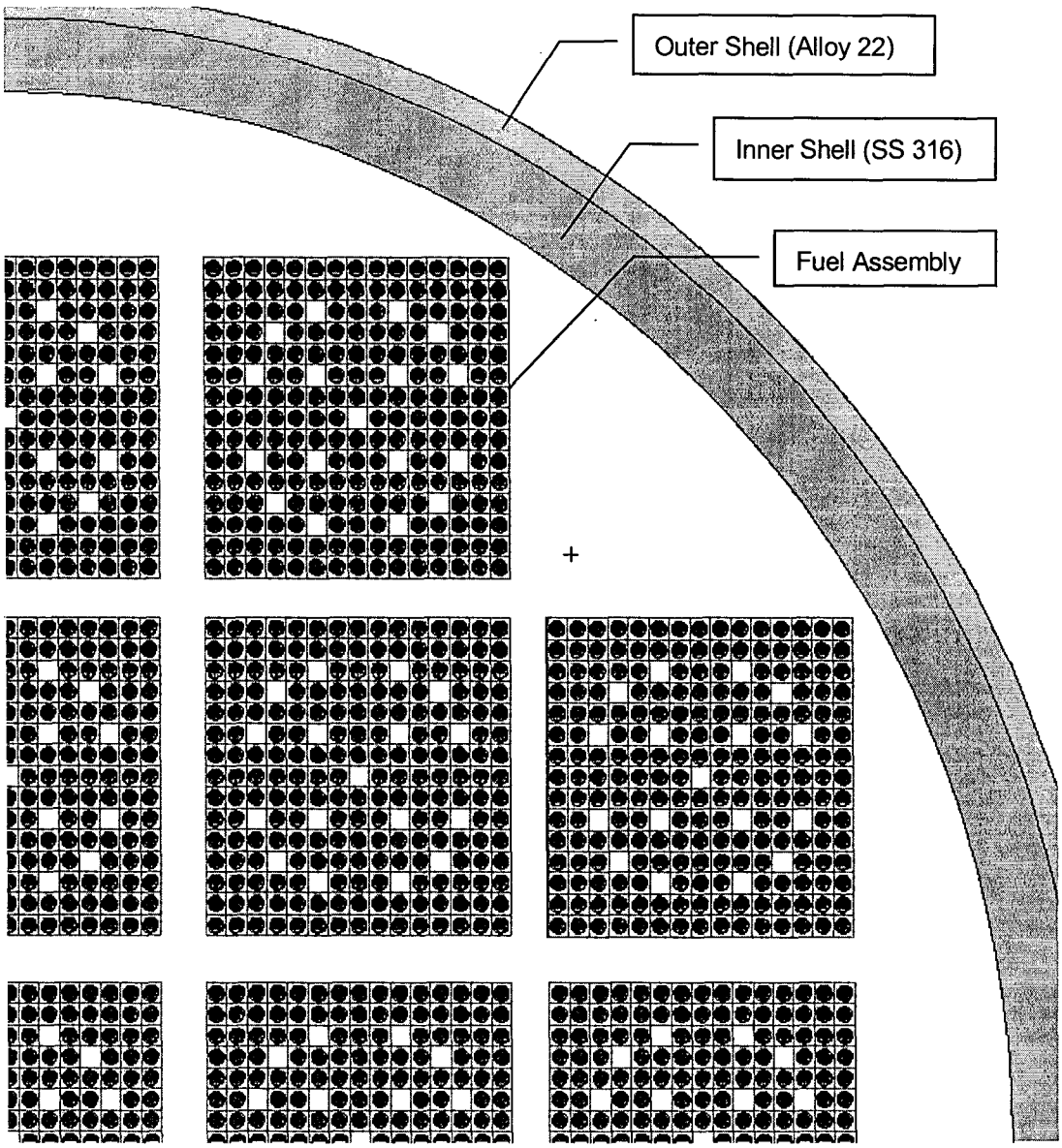



Figure 3. Partial Lateral View of the WP Active Fuel Region in MCNP Calculations

Table 8. Chemical Composition of the Plenum Region[a]

| Element/Isotope | Mass (g) | Nuclide Identification[c] | Atomic Mass[b] (g/mole) | Atom Density (atoms/b•cm) |
|---|---|---|---|---|
| Ni | 537.3145 | 28000.01p | 58.6934 | 3.8865E-04 |
| Cr | 212.05881 | 24000.01p | 51.9961 | 1.7314E-04 |
| Fe | 218.6757 | 26000.01p | 55.845 | 1.6624E-04 |
| Nb | 53.3 | 41093.01p | 92.90638 | 2.4356E-05 |
| Mo | 31.72 | 42000.01p | 95.94 | 1.4036E-05 |
| Ti | 9.36 | 22000.01p | 47.867 | 8.3016E-06 |
| Al | 5.2 | 13027.01p | 26.981538 | 8.1820E-06 |
| Co | 10.4 | 27059.01p | 58.9332 | 7.4920E-06 |
| Mn | 4.021 | 25055.01p | 54.938049 | 3.1073E-06 |
| Si | 3.782875 | 14000.01p | 28.0855 | 5.7183E-06 |
| Cu | 3.12 | 29000.01p | 63.546 | 2.0844E-06 |
| C | 0.860575 | 6000.01p | 12.0107 | 3.0419E-06 |
| S | 0.161715 | 16000.01p | 32.066 | 2.1411E-07 |
| P | 0.1645725 | 15031.01p | 30.973761 | 2.2557E-07 |
| B | 0.0624 | N/A | 10.811 | 2.4504E-07 |
| $^{10}$B (19.9 at%) | N/A | 5010.01p | N/A | 4.8764E-08 |
| $^{11}$B (80.1 at%) | N/A | 5011.01p | N/A | 3.9060E-08 |
| Sn | 139.0715 | 50000.01p | 118.71 | 4.9736E-05 |
| O | 11.988922 | 8016.01p | 15.994915 | 3.1822E-05 |
| Zr | 9408.906 | 40000.01p | 91.224 | 4.3788E-03 |
| N | 0.01905 | 7014.01p | 14.003074 | 5.7741E-08 |
| **Total** | N/A | NIA | N/A | 5.2653E-03 |

SOURCE: [a]BSC 2001, Attachment I, Table I-10.
[b]Parrington et al. 1996.
[c]Briesmeister 1997, Appendix G.

Table 9. Chemical Composition of the Top End-Fitting Region[a]

| Element/Isotope | Mass (g) | Nuclide Identification[c] | Atomic Mass[b] (g/mole) | Atom Density (atoms/b•cm) |
|---|---|---|---|---|
| C | 4.158 | 6000.01p | 12.0107 | 2.1977E-05 |
| Mn | 143.55 | 25055.01p | 54.93805 | 1.6587E-04 |
| P | 0.5265 | 15031.01p | 30.97376 | 1.0791E-06 |
| S | 0.441 | 16000.01p | 32.066 | 8.7305E-07 |
| Si | 178.375 | 14000.01p | 28.0855 | 4.0318E-04 |
| Cr | 2044.4 | 24000.01p | 51.9961 | 2.4960E-03 |
| Ni | 1822.55 | 28000.01p | 58.6934 | 1.9712E-03 |
| N | 0.57 | 7014.01p | 14.003074 | 2.5840E-06 |
| Fe | 6159.8215 | 26000.01p | 55.845 | 7.0021E-03 |
| Mo | 264.65 | 42000.01p | 95.94 | 1.7511E-04 |
| Nb | 92.25 | 41093.01p | 92.90638 | 6.3033E-05 |
| Ti | 16.2 | 22000.01p | 47.867 | 2.1485E-05 |
| Al | 9 | 13027.01p | 26.98154 | 2.1175E-05 |

Originator: JST Date: 9/13/02 Checker: GR Date: 9/16/02

| | | | | |
|---|---|---|---|---|
| Co | 18 | 27059.01p | 58.9332 | 1.9389E-05 |
| Cu | 5.4 | 29000.01p | 63.546 | 5.3945E-06 |
| B | 0.108 | NIA | 10.811 | 6.3417E-07 |
| $^{10}$B (19.9 at%) | N/A | 5010.01p | N/A | 1.2620E-07 |
| $^{11}$B (80.1 at%) | NIA | 5011.01p | NIA | 5.0797E-07 |
| **Total** | 10760 | N/A | N/A | 1.2371E-02 |

SOURCE: [a]BSC 2001, Attachment I, Table 1-13.
[b]Parrington et al. 1996.
[c]Briesmeister 1997, Appendix G.

## 5.3 RADIATION SOURCES

Neutron and gamma radiation sources for the time period between ten and one million years are obtained from CRWMS M&O (1999c, disk 1 of 5), and presented in Tables 10 and 11, respectively. The neutron source spectra per assembly are presented in eight energy groups, starting from 20 MeV and descending to the thermal energy. There are no neutrons below energy of 0.1 MeV. The total neutron source intensities per WP are provided in the last column. The gamma source spectra per assembly are given in 18 energy groups, starting from 10 keV and ascending to 10 MeV. Finally, the total gamma source intensities in the WP are included in the last column of Table 11.

The neutron source spectra per assembly for the time period of one to one million years are depicted in Figure 4. It is noted that the spectra are nearly identical for the all time steps. Therefore, only one MCNP calculation is needed, and the results for all time steps can be obtained by scaling the tallies to the source intensity of each time step.

Table 10. Neutron Source Spectra (n/s) of the Average PWR SNF Assembly

| Age (Years) | Upper Energy Boundary (MeV) | | | | | | | | Total per WP |
|---|---|---|---|---|---|---|---|---|---|
| | 2.00E+01 | 6.43E+00 | 3.00E+00 | 1.85E+00 | 1.40E+00 | 9.00E-01 | 4.00E-01 | 1.00E-01 | |
| 1 | 9.92E+06 | 1.16E+08 | 1.27E+08 | 7.02E+07 | 9.49E+07 | 1.04E+08 | 2.03E+07 | 0.00E+00 | 1.14E+10 |
| 2 | 8.88E+06 | 1.01E+08 | 1.11E+08 | 6.27E+07 | 8.50E+07 | 9.29E+07 | 1.82E+07 | 0.00E+00 | 1.01E+10 |
| 3 | 8.40E+06 | 9.52E+07 | 1.05E+08 | 5.93E+07 | 8.05E+07 | 8.79E+07 | 1.72E+07 | 0.00E+00 | 9.52E+09 |
| 4 | 8.06E+06 | 9.12E+07 | 1.01E+08 | 5.69E+07 | 7.72E+07 | 8.43E+07 | 1.65E+07 | 0.00E+00 | 9.14E+09 |
| 5 | 7.75E+06 | 8.77E+07 | 9.67E+07 | 5.47E+07 | 7.42E+07 | 8.10E+07 | 1.59E+07 | 0.00E+00 | 8.78E+09 |
| 7 | 7.18E+06 | 8.13E+07 | 8.97E+07 | 5.07E+07 | 6.88E+07 | 7.51E+07 | 1.47E+07 | 0.00E+00 | 8.14E+09 |
| 10 | 6.40E+06 | 7.27E+07 | 8.04E+07 | 4.54E+07 | 6.14E+07 | 6.70E+07 | 1.31E+07 | 0.00E+00 | 7.27E+09 |
| 15 | 5.30E+06 | 6.04E+07 | 6.70E+07 | 3.77E+07 | 5.09E+07 | 5.55E+07 | 1.09E+07 | 0.00E+00 | 6.04E+09 |
| 20 | 4.40E+06 | 5.02E+07 | 5.60E+07 | 3.14E+07 | 4.23E+07 | 4.60E+07 | 9.01E+06 | 0.00E+00 | 5.03E+09 |
| 25 | 3.65E+06 | 4.18E+07 | 4.69E+07 | 2.61E+07 | 3.52E+07 | 3.82E+07 | 7.48E+06 | 0.00E+00 | 4.19E+09 |
| 30 | 3.03E+06 | 3.49E+07 | 3.93E+07 | 2.18E+07 | 2.93E+07 | 3.18E+07 | 6.22E+06 | 0.00E+00 | 3.49E+09 |
| 35 | 2.52E+06 | 2.92E+07 | 3.31E+07 | 1.82E+07 | 2.44E+07 | 2.64E+07 | 5.17E+06 | 0.00E+00 | 2.92E+09 |
| 40 | 2.10E+06 | 2.44E+07 | 2.80E+07 | 1.53E+07 | 2.04E+07 | 2.20E+07 | 4.31E+06 | 0.00E+00 | 2.45E+09 |
| 45 | 1.75E+06 | 2.05E+07 | 2.37E+07 | 1.29E+07 | 1.71E+07 | 1.84E+07 | 3.60E+06 | 0.00E+00 | 2.06E+09 |
| 50 | 1.46E+06 | 1.73E+07 | 2.02E+07 | 1.09E+07 | 1.43E+07 | 1.54E+07 | 3.01E+06 | 0.00E+00 | 1.73E+09 |
| 60 | 1.03E+06 | 1.24E+07 | 1.48E+07 | 7.80E+06 | 1.02E+07 | 1.09E+07 | 2.13E+06 | 0.00E+00 | 1.24E+09 |
| 70 | 7.36E+05 | 9.05E+06 | 1.11E+07 | 5.72E+06 | 7.34E+06 | 7.78E+06 | 1.52E+06 | 0.00E+00 | 9.08E+08 |
| 80 | 5.34E+05 | 6.76E+06 | 8.62E+06 | 4.29E+06 | 5.41E+06 | 5.67E+06 | 1.11E+06 | 0.00E+00 | 6.80E+08 |
| 100 | 3.03E+05 | 4.10E+06 | 5.66E+06 | 2.64E+06 | 3.18E+06 | 3.25E+06 | 6.33E+05 | 0.00E+00 | 4.15E+08 |
| 150 | 1.30E+05 | 2.06E+06 | 3.27E+06 | 1.36E+06 | 1.49E+06 | 1.43E+06 | 2.78E+05 | 0.00E+00 | 2.10E+08 |
| 200 | 1.04E+05 | 1.68E+06 | 2.72E+06 | 1.11E+06 | 1.21E+06 | 1.15E+06 | 2.22E+05 | 0.00E+00 | 1.72E+08 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 250 | 9.89E+04 | 1.56E+06 | 2.50E+06 | 1.03E+06 | 1.13E+06 | 1.09E+06 | 2.11E+05 | 0.00E+00 | 1.60E+08 |
| 300 | 9.79E+04 | 1.50E+06 | 2.35E+06 | 9.84E+05 | 1.10E+06 | 1.07E+06 | 2.08E+05 | 0.00E+00 | 1.54E+08 |
| 350 | 9.73E+04 | 1.45E+06 | 2.23E+06 | 9.47E+05 | 1.07E+06 | 1.06E+06 | 2.06E+05 | 0.00E+00 | 1.48E+08 |
| 400 | 9.67E+04 | 1.41E+06 | 2.14E+06 | 9.17E+05 | 1.05E+06 | 1.04E+06 | 2.04E+05 | 0.00E+00 | 1.44E+08 |
| 500 | 9.54E+04 | 1.35E+06 | 1.98E+06 | 8.70E+05 | 1.01E+06 | 1.02E+06 | 2.01E+05 | 0.00E+00 | 1.37E+08 |
| 700 | 9.31E+04 | 1.26E+06 | 1.76E+06 | 8.01E+05 | 9.61E+05 | 9.92E+05 | 1.95E+05 | 0.00E+00 | 1.27E+08 |
| 1000 | 9.00E+04 | 1.16E+06 | 1.54E+06 | 7.30E+05 | 9.03E+05 | 9.51E+05 | 1.87E+05 | 0.00E+00 | 1.17E+08 |
| 1500 | 8.51E+04 | 1.06E+06 | 1.31E+06 | 6.50E+05 | 8.31E+05 | 8.93E+05 | 1.76E+05 | 0.00E+00 | 1.05E+08 |
| 2000 | 8.06E+04 | 9.92E+05 | 1.18E+06 | 5.96E+05 | 7.76E+05 | 8.42E+05 | 1.66E+05 | 0.00E+00 | 9.73E+07 |
| 2500 | 7.63E+04 | 9.32E+05 | 1.09E+06 | 5.58E+05 | 7.31E+05 | 7.96E+05 | 1.57E+05 | 0.00E+00 | 9.11E+07 |
| 3000 | 7.24E+04 | 8.80E+05 | 1.03E+06 | 5.26E+05 | 6.91E+05 | 7.54E+05 | 1.49E+05 | 0.00E+00 | 8.62E+07 |
| 3500 | 6.86E+04 | 8.34E+05 | 9.70E+05 | 4.98E+05 | 6.55E+05 | 7.15E+05 | 1.41E+05 | 0.00E+00 | 8.15E+07 |
| 4000 | 6.52E+04 | 7.91E+05 | 9.20E+05 | 4.73E+05 | 6.22E+05 | 6.79E+05 | 1.34E+05 | 0.00E+00 | 7.74E+07 |
| 4500 | 6.19E+04 | 7.53E+05 | 8.76E+05 | 4.50E+05 | 5.91E+05 | 6.45E+05 | 1.27E+05 | 0.00E+00 | 7.36E+07 |
| 5000 | 5.89E+04 | 7.16E+05 | 8.34E+05 | 4.28E+05 | 5.62E+05 | 6.14E+05 | 1.21E+05 | 0.00E+00 | 7.00E+07 |
| 5500 | 5.61E+04 | 6.83E+05 | 7.96E+05 | 4.08E+05 | 5.36E+05 | 5.84E+05 | 1.15E+05 | 0.00E+00 | 6.67E+07 |
| 6000 | 5.34E+04 | 6.51E+05 | 7.59E+05 | 3.89E+05 | 5.11E+05 | 5.57E+05 | 1.10E+05 | 0.00E+00 | 6.36E+07 |
| 6500 | 5.06E+04 | 6.22E+05 | 7.24E+05 | 3.73E+05 | 4.89E+05 | 5.30E+05 | 1.04E+05 | 0.00E+00 | 6.07E+07 |
| 7000 | 4.80E+04 | 5.94E+05 | 6.91E+05 | 3.58E+05 | 4.69E+05 | 5.04E+05 | 9.87E+04 | 0.00E+00 | 5.80E+07 |
| 7500 | 4.58E+04 | 5.65E+05 | 6.61E+05 | 3.44E+05 | 4.49E+05 | 4.82E+05 | 9.42E+04 | 0.00E+00 | 5.55E+07 |
| 8000 | 4.37E+04 | 5.39E+05 | 6.33E+05 | 3.31E+05 | 4.30E+05 | 4.61E+05 | 9.01E+04 | 0.00E+00 | 5.31E+07 |
| 8500 | 4.19E+04 | 5.16E+05 | 6.07E+05 | 3.17E+05 | 4.12E+05 | 4.41E+05 | 8.63E+04 | 0.00E+00 | 5.08E+07 |
| 9000 | 4.01E+04 | 4.95E+05 | 5.83E+05 | 3.04E+05 | 3.95E+05 | 4.23E+05 | 8.27E+04 | 0.00E+00 | 4.88E+07 |
| 9500 | 3.85E+04 | 4.75E+05 | 5.60E+05 | 2.92E+05 | 3.79E+05 | 4.05E+05 | 7.93E+04 | 0.00E+00 | 4.68E+07 |
| 10000 | 3.69E+04 | 4.57E+05 | 5.38E+05 | 2.80E+05 | 3.64E+05 | 3.89E+05 | 7.61E+04 | 0.00E+00 | 4.50E+07 |
| 15000 | 2.60E+04 | 3.23E+05 | 3.83E+05 | 1.98E+05 | 2.57E+05 | 2.74E+05 | 5.36E+04 | 0.00E+00 | 3.18E+07 |
| 20000 | 2.02E+04 | 2.51E+05 | 2.98E+05 | 1.54E+05 | 2.00E+05 | 2.13E+05 | 4.17E+04 | 0.00E+00 | 2.47E+07 |
| 25000 | 1.71E+04 | 2.12E+05 | 2.50E+05 | 1.30E+05 | 1.69E+05 | 1.80E+05 | 3.53E+04 | 0.00E+00 | 2.09E+07 |
| 30000 | 1.54E+04 | 1.89E+05 | 2.21E+05 | 1.16E+05 | 1.52E+05 | 1.62E+05 | 3.18E+04 | 0.00E+00 | 1.86E+07 |
| 35000 | 1.45E+04 | 1.75E+05 | 2.04E+05 | 1.08E+05 | 1.42E+05 | 1.52E+05 | 2.97E+04 | 0.00E+00 | 1.73E+07 |
| 40000 | 1.39E+04 | 1.67E+05 | 1.93E+05 | 1.03E+05 | 1.35E+05 | 1.46E+05 | 2.85E+04 | 0.00E+00 | 1.65E+07 |
| 45000 | 1.35E+04 | 1.61E+05 | 1.85E+05 | 9.94E+04 | 1.31E+05 | 1.42E+05 | 2.77E+04 | 0.00E+00 | 1.60E+07 |
| 50000 | 1.32E+04 | 1.57E+05 | 1.79E+05 | 9.69E+04 | 1.29E+05 | 1.39E+05 | 2.72E+04 | 0.00E+00 | 1.56E+07 |
| 55000 | 1.30E+04 | 1.54E+05 | 1.75E+05 | 9.50E+04 | 1.26E+05 | 1.37E+05 | 2.68E+04 | 0.00E+00 | 1.53E+07 |
| 60000 | 1.29E+04 | 1.51E+05 | 1.71E+05 | 9.34E+04 | 1.25E+05 | 1.35E+05 | 2.64E+04 | 0.00E+00 | 1.50E+07 |
| 65000 | 1.27E+04 | 1.49E+05 | 1.68E+05 | 9.20E+04 | 1.23E+05 | 1.34E+05 | 2.61E+04 | 0.00E+00 | 1.48E+07 |
| 70000 | 1.26E+04 | 1.47E+05 | 1.65E+05 | 9.08E+04 | 1.22E+05 | 1.32E+05 | 2.59E+04 | 0.00E+00 | 1.46E+07 |
| 75000 | 1.25E+04 | 1.45E+05 | 1.62E+05 | 8.97E+04 | 1.20E+05 | 1.31E+05 | 2.56E+04 | 0.00E+00 | 1.44E+07 |
| 80000 | 1.24E+04 | 1.43E+05 | 1.60E+05 | 8.86E+04 | 1.19E+05 | 1.30E+05 | 2.53E+04 | 0.00E+00 | 1.42E+07 |
| 85000 | 1.22E+04 | 1.41E+05 | 1.58E+05 | 8.76E+04 | 1.18E+05 | 1.28E+05 | 2.51E+04 | 0.00E+00 | 1.41E+07 |
| 90000 | 1.21E+04 | 1.40E+05 | 1.56E+05 | 8.67E+04 | 1.17E+05 | 1.27E+05 | 2.49E+04 | 0.00E+00 | 1.39E+07 |
| 95000 | 1.20E+04 | 1.38E+05 | 1.54E+05 | 8.57E+04 | 1.16E+05 | 1.26E+05 | 2.46E+04 | 0.00E+00 | 1.38E+07 |
| 100000 | 1.19E+04 | 1.37E+05 | 1.52E+05 | 8.49E+04 | 1.14E+05 | 1.25E+05 | 2.44E+04 | 0.00E+00 | 1.36E+07 |
| 150000 | 1.09E+04 | 1.24E+05 | 1.37E+05 | 7.70E+04 | 1.04E+05 | 1.14E+05 | 2.22E+04 | 0.00E+00 | 1.24E+07 |
| 200000 | 9.90E+03 | 1.13E+05 | 1.25E+05 | 7.03E+04 | 9.50E+04 | 1.04E+05 | 2.03E+04 | 0.00E+00 | 1.13E+07 |
| 250000 | 9.03E+03 | 1.04E+05 | 1.15E+05 | 6.43E+04 | 8.67E+04 | 9.45E+04 | 1.85E+04 | 0.00E+00 | 1.03E+07 |
| 300000 | 8.23E+03 | 9.46E+04 | 1.05E+05 | 5.88E+04 | 7.92E+04 | 8.62E+04 | 1.69E+04 | 0.00E+00 | 9.43E+06 |
| 350000 | 7.51E+03 | 8.65E+04 | 9.64E+04 | 5.37E+04 | 7.23E+04 | 7.87E+04 | 1.54E+04 | 0.00E+00 | 8.62E+06 |
| 400000 | 6.85E+03 | 7.91E+04 | 8.84E+04 | 4.91E+04 | 6.60E+04 | 7.18E+04 | 1.41E+04 | 0.00E+00 | 7.88E+06 |
| 450000 | 6.25E+03 | 7.24E+04 | 8.10E+04 | 4.49E+04 | 6.03E+04 | 6.55E+04 | 1.28E+04 | 0.00E+00 | 7.21E+06 |
| 500000 | 5.71E+03 | 6.62E+04 | 7.42E+04 | 4.10E+04 | 5.50E+04 | 5.98E+04 | 1.17E+04 | 0.00E+00 | 6.59E+06 |
| 550000 | 5.21E+03 | 6.06E+04 | 6.81E+04 | 3.75E+04 | 5.03E+04 | 5.46E+04 | 1.07E+04 | 0.00E+00 | 6.03E+06 |
| 600000 | 4.75E+03 | 5.55E+04 | 6.25E+04 | 3.44E+04 | 4.60E+04 | 4.98E+04 | 9.76E+03 | 0.00E+00 | 5.52E+06 |
| 650000 | 4.34E+03 | 5.08E+04 | 5.73E+04 | 3.14E+04 | 4.20E+04 | 4.55E+04 | 8.91E+03 | 0.00E+00 | 5.05E+06 |
| 700000 | 3.97E+03 | 4.65E+04 | 5.26E+04 | 2.88E+04 | 3.84E+04 | 4.16E+04 | 8.14E+03 | 0.00E+00 | 4.62E+06 |
| 750000 | 3.62E+03 | 4.26E+04 | 4.84E+04 | 2.64E+04 | 3.51E+04 | 3.80E+04 | 7.44E+03 | 0.00E+00 | 4.23E+06 |
| 800000 | 3.31E+03 | 3.91E+04 | 4.45E+04 | 2.42E+04 | 3.21E+04 | 3.47E+04 | 6.80E+03 | 0.00E+00 | 3.88E+06 |
| 850000 | 3.03E+03 | 3.59E+04 | 4.09E+04 | 2.22E+04 | 2.94E+04 | 3.18E+04 | 6.22E+03 | 0.00E+00 | 3.56E+06 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 900000 | 2.77E+03 | 3.29E+04 | 3.77E+04 | 2.03E+04 | 2.69E+04 | 2.91E+04 | 5.69E+03 | 0.00E+00 | 3.26E+06 |
| 950000 | 2.53E+03 | 3.02E+04 | 3.47E+04 | 1.87E+04 | 2.47E+04 | 2.66E+04 | 5.20E+03 | 0.00E+00 | 3.00E+06 |
| 1000000 | 2.32E+03 | 2.78E+04 | 3.20E+04 | 1.71E+04 | 2.26E+04 | 2.43E+04 | 4.76E+03 | 0.00E+00 | 2.75E+06 |

SOURCE: CRWMS M&O 1999c, disk 1 of 5, file PWR.neutron.

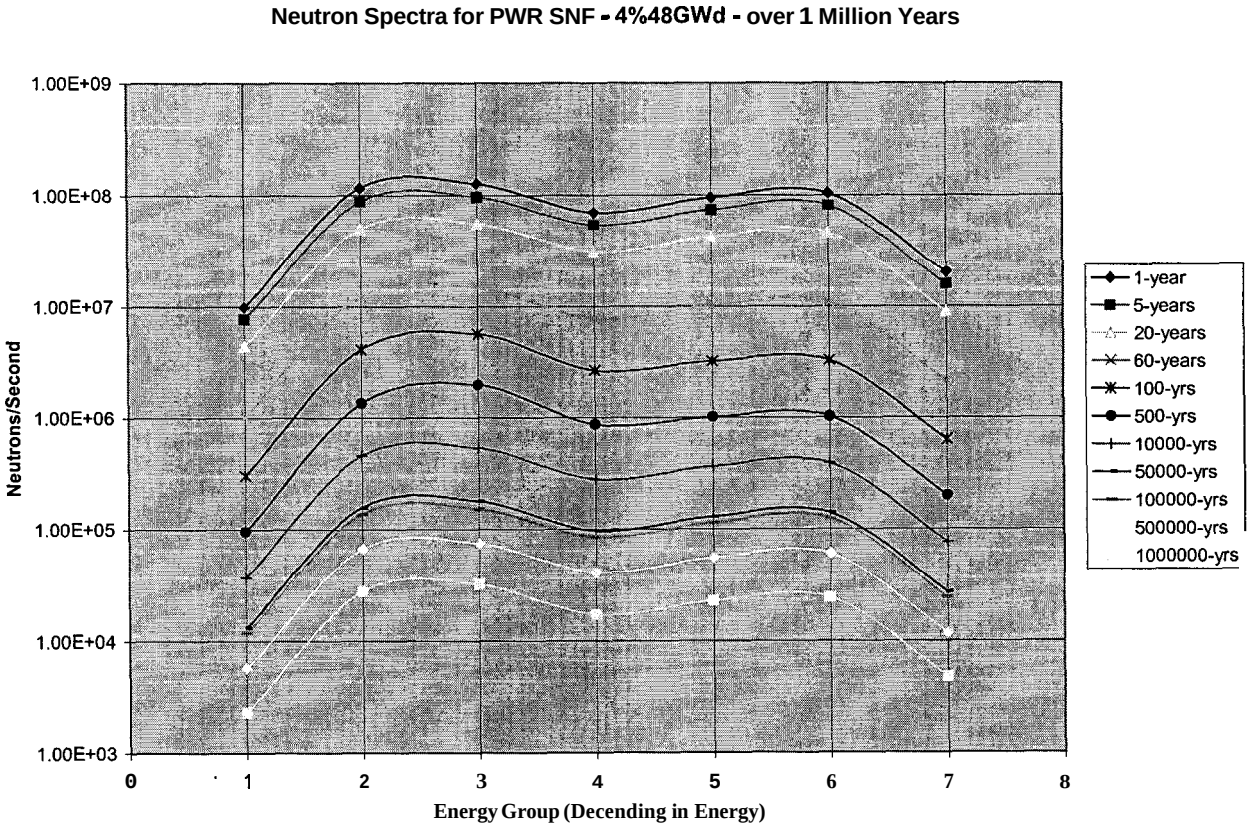



Figure 4. Neutron Source Spectra of the Average PWR SNF Assembly

Table 11. Gamma Source Spectra (p/s) of the Average PWR SNF Assembly

| Age (Years) | Upper Energy Boundary (MeV) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5.00E-02 | 1.00E-01 | 2.00E-01 | 3.00E-01 | 4.00E-01 | 6.00E-01 | 8.00E-01 |
| 10 | 1.02E+15 | 2.83E+14 | 2.07E+14 | 6.07E+13 | 3.95E+13 | 1.69E+14 | 1.90E+15 |
| 15 | 8.70E+14 | 2.47E+14 | 1.71E+14 | 5.15E+13 | 3.39E+13 | 5.28E+13 | 1.59E+15 |
| 20 | 7.61E+14 | 2.21E+14 | 1.46E+14 | 4.46E+13 | 2.98E+13 | 2.79E+13 | 1.39E+15 |
| 25 | 6.70E+14 | 1.99E+14 | 1.26E+14 | 3.89E+13 | 2.63E+13 | 2.05E+13 | 1.24E+15 |
| 35 | 5.24E+14 | 1.63E+14 | 9.57E+13 | 2.98E+13 | 2.05E+13 | 1.46E+13 | 9.78E+14 |
| 50 | 3.66E+14 | 1.22E+14 | 6.47E+13 | 2.04E+13 | 1.42E+13 | 9.67E+12 | 6.90E+14 |
| 70 | 2.30E+14 | 8.58E+13 | 3.93E+13 | 1.25E+13 | 8.66E+12 | 5.79E+12 | 4.34E+14 |
| 100 | 1.17E+14 | 5.49E+13 | 1.90E+13 | 6.08E+12 | 4.16E+12 | 2.75E+12 | 2.17E+14 |
| 150 | 4.25E+13 | 3.33E+13 | 5.85E+12 | 1.95E+12 | 1.24E+12 | 8.11E+11 | 6.84E+13 |
| 200 | 1.94E+13 | 2.57E+13 | 2.00E+12 | 7.40E+11 | 3.87E+11 | 2.46E+11 | 2.16E+13 |
| 250 | 1.19E+13 | 2.22E+13 | 8.61E+11 | 3.85E+11 | 1.38E+11 | 8.11E+10 | 6.83E+12 |
| 350 | 7.80E+12 | 1.84E+13 | 4.22E+11 | 2.48E+11 | 4.36E+10 | 1.88E+10 | 7.27E+11 |
| 500 | 5.99E+12 | 1.46E+13 | 3.72E+11 | 2.32E+11 | 3.54E+10 | 1.31E+10 | 7.63E+10 |
| 700 | 4.57E+12 | 1.07E+13 | 3.61E+11 | 2.28E+11 | 3.56E+10 | 1.29E+10 | 5.52E+10 |
| 1000 | 3.21E+12 | 6.87E+12 | 3.49E+11 | 2.21E+11 | 3.57E+10 | 1.29E+10 | 5.46E+10 |
| 1500 | 1.98E+12 | 3.39E+12 | 3.31E+11 | 2.11E+11 | 3.54E+10 | 1.29E+10 | 5.40E+10 |

Originator: JST Date: 9/16/02 Checker: GR Date: 9/16/02

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2000 | 1.41E+12 | 1.82E+12 | 3.15E+11 | 2.02E+11 | 3.47E+10 | 1.29E+10 | 5.35E+10 |
| 2500 | 1.14E+12 | 1.10E+12 | 3.00E+11 | 1.93E+11 | 3.38E+10 | 1.28E+10 | 5.31E+10 |
| 3500 | 9.04E+11 | 6.02E+11 | 2.74E+11 | 1.76E+11 | 3.21E+10 | 1.27E+10 | 5.23E+10 |
| 5000 | 7.66E+11 | 4.38E+11 | 2.39E+11 | 1.53E+11 | 2.98E+10 | 1.26E+10 | 5.11E+10 |
| 7000 | 6.47E+11 | 3.61E+11 | 1.99E+11 | 1.28E+11 | 2.71E+10 | 1.25E+10 | 4.97E+10 |
| 10000 | 5.11E+11 | 2.80E+11 | 1.51E+11 | 9.76E+10 | 2.42E+10 | 1.23E+10 | 4.79E+10 |
| 15000 | 3.55E+11 | 1.88E+11 | 9.72E+10 | 6.31E+10 | 2.10E+10 | 1.21E+10 | 4.52E+10 |
| 20000 | 2.58E+11 | 1.31E+11 | 6.34E+10 | 4.18E+10 | 1.93E+10 | 1.19E+10 | 4.29E+10 |
| 25000 | 1.97E+11 | 9.58E+10 | 4.24E+10 | 2.88E+10 | 1.85E+10 | 1.18E+10 | 4.10E+10 |
| 35000 | 1.33E+11 | 6.06E+10 | 2.14E+10 | 1.62E+10 | 1.83E+10 | 1.15E+10 | 3.80E+10 |
| 50000 | 9.76E+10 | 4.50E+10 | 1.18E+10 | 1.13E+10 | 1.94E+10 | 1.12E+10 | 3.49E+10 |
| 70000 | 8.27E+10 | 4.27E+10 | 1.01E+10 | 1.15E+10 | 2.11E+10 | 1.08E+10 | 3.24E+10 |
| 100000 | 7.69E+10 | 4.48E+10 | 1.10E+10 | 1.34E+10 | 2.31E+10 | 1.03E+10 | 3.01E+10 |
| 150000 | 7.68E+10 | 4.81E+10 | 1.26E+10 | 1.57E+10 | 2.49E+10 | 9.78E+09 | 2.76E+10 |
| 200000 | 7.79E+10 | 4.96E+10 | 1.35E+10 | 1.66E+10 | 2.52E+10 | 9.35E+09 | 2.50E+10 |
| 250000 | 7.81E+10 | 5.01E+10 | 1.39E+10 | 1.67E+10 | 2.47E+10 | 9.04E+09 | 2.24E+10 |
| 350000 | 7.64E+10 | 4.94E+10 | 1.41E+10 | 1.57E+10 | 2.27E+10 | 8.62E+09 | 1.77E+10 |
| 500000 | 7.14E+10 | 4.69E+10 | 1.35E+10 | 1.36E+10 | 1.94E+10 | 8.21E+09 | 1.25E+10 |
| 700000 | 6.46E+10 | 4.31E+10 | 1.25E+10 | 1.13E+10 | 1.59E+10 | 7.75E+09 | 8.22E+09 |
| 1000000 | 5.65E+10 | 3.82E+10 | 1.11E+10 | 9.00E+09 | 1.27E+10 | 7.07E+09 | 5.14E+09 |

Table 11. Gamma Source Spectra (p/s) of the Average PWR SNF Assembly (Continued)

| Age (Years) | Upper Energy Boundary (MeV) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1.00E+00 | 1.33E+00 | 1.66E+00 | 2.00E+00 | 2.50E+00 | 3.00E+00 | 4.00E+00 |
| 10 | 8.96E+13 | 1.55E+14 | 3.62E+13 | 1.30E+11 | 4.73E+10 | 3.05E+09 | 3.82E+08 |
| 15 | 3.18E+13 | 8.64E+13 | 1.79E+13 | 8.84E+10 | 5.70E+09 | 4.02E+08 | 4.03E+07 |
| 20 | 1.67E+13 | 4.98E+13 | 9.42E+12 | 7.68E+10 | 4.09E+09 | 3.05E+08 | 2.43E+07 |
| 25 | 1.10E+13 | 2.95E+13 | 5.13E+12 | 6.75E+10 | 3.53E+09 | 2.88E+08 | 1.98E+07 |
| 35 | 5.88E+12 | 1.12E+13 | 1.68E+12 | 5.24E+10 | 2.70E+09 | 2.57E+08 | 1.37E+07 |
| 50 | 2.79E+12 | 3.33E+12 | 4.39E+11 | 3.60E+10 | 1.85E+09 | 2.17E+08 | 7.99E+06 |
| 70 | 1.31E+12 | 1.03E+12 | 1.51E+11 | 2.19E+10 | 1.13E+09 | 1.75E+08 | 4.04E+06 |
| 100 | 5.67E+11 | 3.40E+11 | 6.02E+10 | 1.05E+10 | 5.38E+08 | 1.29E+08 | 1.69E+06 |
| 150 | 1.79E+11 | 9.10E+10 | 1.71E+10 | 3.06E+09 | 1.58E+08 | 7.77E+07 | 7.48E+05 |
| 200 | 7.04E+10 | 2.68E+10 | 5.03E+09 | 8.97E+08 | 4.70E+07 | 4.75E+07 | 6.01E+05 |
| 250 | 3.88E+10 | 8.15E+09 | 1.51E+09 | 2.67E+08 | 1.48E+07 | 2.91E+07 | 5.72E+05 |
| 350 | 2.67E+10 | 1.11E+09 | 1.84E+08 | 2.97E+07 | 2.97E+06 | 1.12E+07 | 5.56E+05 |
| 500 | 2.55E+10 | 4.54E+08 | 6.40E+07 | 1.03E+07 | 2.72E+06 | 3.02E+06 | 5.45E+05 |
| 700 | 2.53E+10 | 4.28E+08 | 6.34E+07 | 1.42E+07 | 4.38E+06 | 9.79E+05 | 5.37E+05 |
| 1000 | 2.50E+10 | 4.31E+08 | 6.89E+07 | 2.36E+07 | 7.97E+06 | 7.07E+05 | 5.32E+05 |
| 1500 | 2.46E+10 | 4.54E+08 | 8.21E+07 | 4.57E+07 | 1.64E+07 | 7.98E+05 | 5.36E+05 |
| 2000 | 2.42E+10 | 4.87E+08 | 9.92E+07 | 7.43E+07 | 2.73E+07 | 9.50E+05 | 5.53E+05 |
| 2500 | 2.38E+10 | 5.25E+08 | 1.20E+08 | 1.08E+08 | 4.02E+07 | 1.14E+06 | 5.79E+05 |
| 3500 | 2.31E+10 | 6.16E+08 | 1.67E+08 | 1.87E+08 | 7.04E+07 | 1.59E+06 | 6.53E+05 |
| 5000 | 2.20E+10 | 7.74E+08 | 2.50E+08 | 3.24E+08 | 1.23E+08 | 2.39E+06 | 7.99E+05 |
| 7000 | 2.06E+10 | 1.00E+09 | 3.71E+08 | 5.23E+08 | 1.99E+08 | 3.58E+06 | 1.03E+06 |
| 10000 | 1.88E+10 | 1.36E+09 | 5.58E+08 | 8.30E+08 | 3.16E+08 | 5.44E+06 | 1.41E+06 |
| 15000 | 1.61E+10 | 1.94E+09 | 8.65E+08 | 1.33E+09 | 5.06E+08 | 8.51E+06 | 2.07E+06 |
| 20000 | 1.38E+10 | 2.48E+09 | 1.16E+09 | 1.80E+09 | 6.87E+08 | 1.14E+07 | 2.72E+06 |
| 25000 | 1.20E+10 | 3.00E+09 | 1.43E+09 | 2.25E+09 | 8.58E+08 | 1.42E+07 | 3.35E+06 |
| 35000 | 9.05E+09 | 3.94E+09 | 1.94E+09 | 3.06E+09 | 1.17E+09 | 1.93E+07 | 4.51E+06 |
| 50000 | 6.23E+09 | 5.15E+09 | 2.60E+09 | 4.10E+09 | 1.57E+09 | 2.58E+07 | 6.00E+06 |
| 70000 | 4.22E+09 | 6.42E+09 | 3.30E+09 | 5.20E+09 | 1.99E+09 | 3.27E+07 | 7.58E+06 |
| 100000 | 2.99E+09 | 7.75E+09 | 4.05E+09 | 6.36E+09 | 2.43E+09 | 4.00E+07 | 9.24E+06 |
| 150000 | 2.52E+09 | 9.00E+09 | 4.78E+09 | 7.46E+09 | 2.85E+09 | 4.69E+07 | 1.08E+07 |
| 200000 | 2.40E+09 | 9.25E+09 | 4.98E+09 | 7.69E+09 | 2.94E+09 | 4.83E+07 | 1.11E+07 |
| 250000 | 2.28E+09 | 9.01E+09 | 4.92E+09 | 7.51E+09 | 2.87E+09 | 4.72E+07 | 1.09E+07 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 350000 | 1.98E+09 | 7.91E+09 | 4.43E+09 | 6.59E+09 | 2.52E+09 | 4.14E+07 | 9.55E+06 |
| 500000 | 1.52E+09 | 6.05E+09 | 3.54E+09 | 5.03E+09 | 1.92E+09 | 3.16E+07 | 7.28E+06 |
| 700000 | 1.08E+09 | 4.20E+09 | 2.61E+09 | 3.47E+09 | 1.32E+09 | 2.19E+07 | 5.02E+06 |
| 1000000 | 7.30E+08 | 2.70E+09 | 1.83E+09 | 2.20E+09 | 8.40E+08 | 1.40E+07 | 3.19E+06 |

Table 11. Gamma Source Spectra (p/s) of the Average PWR SNF Assembly (Continued)

| Age | Upper Energy Bound (MeV) | | | | Total per |
|---|---|---|---|---|---|
| (Years) | 5.00E+00 | 6.50E+00 | 8.00E+00 | 1.00E+01 | WP |
| 10 | 1.17E+07 | 4.71E+06 | 9.24E+05 | 1.96E+05 | 8.32E+16 |
| 15 | 9.72E+06 | 3.90E+06 | 7.65E+05 | 1.62E+05 | 6.62E+16 |
| 20 | 8.06E+06 | 3.24E+06 | 6.35E+05 | 1.35E+05 | 5.66E+16 |
| 25 | 6.69E+06 | 2.69E+06 | 5.27E+05 | 1.12E+05 | 4.97E+16 |
| 35 | 4.63E+06 | 1.86E+06 | 3.64E+05 | 7.73E+04 | 3.87E+16 |
| 50 | 2.70E+06 | 1.08E+06 | 2.12E+05 | 4.50E+04 | 2.72E+16 |
| 70 | 1.36E+06 | 5.46E+05 | 1.07E+05 | 2.27E+04 | 1.72E+16 |
| 100 | 5.68E+05 | 2.27E+05 | 4.44E+04 | 9.42E+03 | 8.86E+15 |
| 150 | 2.51E+05 | 9.99E+04 | 1.95E+04 | 4.12E+03 | 3.24E+15 |
| 200 | 2.01E+05 | 8.00E+04 | 1.56E+04 | 3.29E+03 | 1.47E+15 |
| 250 | 1.91E+05 | 7.62E+04 | 1.49E+04 | 3.14E+03 | 8.91E+14 |
| 350 | 1.86E+05 | 7.41E+04 | 1.45E+04 | 3.06E+03 | 5.81E+14 |
| 500 | 1.81E+05 | 7.23E+04 | 1.41E+04 | 2.99E+03 | 4.48E+14 |
| 700 | 1.76E+05 | 7.05E+04 | 1.38E+04 | 2.92E+03 | 3.36E+14 |
| 1000 | 1.70E+05 | 6.81E+04 | 1.33E+04 | 2.82E+03 | 2.26E+14 |
| 1500 | 1.61E+05 | 6.45E+04 | 1.26E+04 | 2.68E+03 | 1.27E+14 |
| 2000 | 1.53E+05 | 6.12E+04 | 1.20E+04 | 2.54E+03 | 8.13E+13 |
| 2500 | 1.45E+05 | 5.81E+04 | 1.14E+04 | 2.42E+03 | 6.00E+13 |
| 3500 | 1.31E+05 | 5.27E+04 | 1.03E+04 | 2.19E+03 | 4.36E+13 |
| 5000 | 1.14E+05 | 4.57E+04 | 8.95E+03 | 1.90E+03 | 3.60E+13 |
| 7000 | 9.56E+04 | 3.83E+04 | 7.51E+03 | 1.59E+03 | 3.04E+13 |
| 10000 | 7.56E+04 | 3.03E+04 | 5.94E+03 | 1.26E+03 | 2.41E+13 |
| 15000 | 5.55E+04 | 2.22E+04 | 4.36E+03 | 9.24E+02 | 1.68E+13 |
| 20000 | 4.47E+04 | 1.79E+04 | 3.51E+03 | 7.45E+02 | 1.24E+13 |
| 25000 | 3.89E+04 | 1.56E+04 | 3.05E+03 | 6.48E+02 | 9.55E+12 |
| 35000 | 3.37E+04 | 1.35E+04 | 2.65E+03 | 5.61E+02 | 6.68E+12 |
| 50000 | 3.11E+04 | 1.25E+04 | 2.45E+03 | 5.19E+02 | 5.27E+12 |
| 70000 | 2.97E+04 | 1.19E+04 | 2.33E+03 | 4.95E+02 | 4.88E+12 |
| 100000 | 2.80E+04 | 1.12E+04 | 2.20E+03 | 4.68E+02 | 4.90E+12 |
| 150000 | 2.55E+04 | 1.02E+04 | 2.01E+03 | 4.26E+02 | 5.09E+12 |
| 200000 | 2.33E+04 | 9.34E+03 | 1.83E+03 | 3.89E+02 | 5.13E+12 |
| 250000 | 2.12E+04 | 8.51E+03 | 1.67E+03 | 3.55E+02 | 5.07E+12 |
| 350000 | 1.77E+04 | 7.09E+03 | 1.39E+03 | 2.95E+02 | 4.79E+12 |
| 500000 | 1.34E+04 | 5.39E+03 | 1.06E+03 | 2.24E+02 | 4.28E+12 |
| 700000 | 9.34E+03 | 3.75E+03 | 7.35E+02 | 1.56E+02 | 3.70E+12 |
| 1000000 | 5.46E+03 | 2.19E+03 | 4.30E+02 | 9.12E+01 | 3.11E+12 |

SOURCE: CRWMS M&O 1999c, disk 1 of 5, file PWR.gamma.

## 5.4 PHYSICAL PROPERTIES OF AIR-WATER VAPOR MIXTURES

The atomic density of the composition of air-water vapor mixture is required in the calculations of nitric acid production in the 21-PWR WP. The mass densities of water vapor and air are needed for computing the atomic density of the moist air composition. For this calculation, the pressure inside the failed WP is assumed to be one atmosphere (Assumption 3.11), and the relative humidity of 40%

and 90% at temperature 30°C and 90°C are used (Assumption 3.11).

Since relative humidity is the ratio of the pressure of water vapor present to the pressure of saturated water vapor at the same temperature, the water vapor pressure in moist air is the product of the relative humidity and the saturated vapor pressure. The air pressure is then the difference of the atmospheric pressure and the water vapor pressure at the given temperature.

Given the temperature and the partial pressures of water vapor and air, the densities of water vapor and air can be determined using the ideal gas law

$$P V = n R T \qquad \text{(Eq. 2)}$$

where
P is the pressure of water vapor or air
V is the volume of water vapor or air
n is the number of moles of water vapor or air
R is the ideal gas constant, 8.31451E+00 joules per mole per kelvin (Parrington et al. 1996, p. 59)
T is the temperature.

Since volume equals to mass divided by density, $V = m/\rho$, the equation above can be rewritten for the density as

$$\rho = \frac{P m}{n R T} = \frac{P \frac{m}{n}}{R T} = \frac{P M}{R T} \qquad \text{(Eq. 3)}$$

where M is the molecular weight.

The density of moist air is sum of the densities of water vapor and air, and with Equation 3 the density of moist air can be expressed as

$$\rho_{ma} = \rho_v + \rho_a = \frac{P_v M_v}{R T} + \frac{P_a M_a}{R T} \qquad \text{(Eq. 4)}$$

where
$\rho_{ma}$ is the density of moist air
$\rho_v$ is the density of water vapor
$\rho_a$ is the density of air
$P_v$ is the partial pressure of water vapor
$P_a$ is the partial pressure of air
$M_v$ is the molecular weight of water vapor
$M_a$ is the molecular weight of air.

Since for a given temperature the partial pressure of water vapor is the product the relative humidity and the saturated pressure, Equation 4 becomes

$$\rho_{ma} = \frac{(RH)\,(P_{sat})\,M_v}{R\,T} + \frac{[\,P_0 - (RH)\,(P_{sat})\,]\,M_a}{R\,T} \qquad \text{(Eq. 5)}$$

where
RH is the relative humidity at temperature T
$P_{sat}$ is the saturated vapor pressure at temperature T
$P_0$ is the pressure at one atmosphere (Assumption 3.11).

Equation 5 provides the relationship to compute the densities of water vapor and air in a water vapor-air mixture as a function of the relative humidity and temperature at pressure $P_0$. From the densities and compositions of water vapor and air, atomic densities of the compositions can be calculated. The saturated vapor pressure as a function of temperature can be found in ASME 1993 (p. 54) and given in Table 12. The composition of air can be found in Weast 1979 (p. F-211) and presented in Table 13.

Table 12. Saturated Vapor Pressure Versus Temperature

| Temperature ("C) | Temperature ("K) | Pressure (Pa) |
|---|---|---|
| 10 | 283.15 | 1227 |
| 20 | 293.15 | 2336.6 |
| 30 | 303.15 | 4241.5 |
| 40 | 313.15 | 7375 |
| 50 | 323.15 | 12335.3 |
| 60 | 333.15 | 19920.2 |
| 70 | 343.15 | 31162 |
| 80 | 353.15 | 47359.8 |

SOURCE: ASME 1993, p. 54.

Table 13. Composition of Air

| Nuclide | Volume Fraction | Atomic Mass |
|---|---|---|
| $N_2$ | 0.78084 | 14.00674 |
| $O_2$ | 0.20946 | 15.9994 |
| Ar | 0.00934 | 39.948 |
| $CO_2$ | 0.00033 | 44.0095 |

SOURCE: Weast 1979, p. F-211.

The atom density of the composition of water vapor-air mixture at various relative humidity and temperature was calculated in the worksheet "AtomDensity" of the Excel file "MoistAirProperties," which is included in the compact disk as Attachment III of this document. Table 14 presents the atom density of the moist air composition at the conditions used in this calculation.

Table 14. Atom Density (atoms/b•cm) of Composition of Water Vapor-Air Mixture

| Relative Humidity and Temperature | N | Ar | C | O | H | Total |
|---|---|---|---|---|---|---|
| RH=40% T=30°C | 3.717E-05 | 2.223E-07 | 7.854E-09 | 1.039E-05 | 8.126E-07 | 4.861E-05 |
| RH=40% T=90°C | 2.284E-05 | 1.366E-07 | 4.827E-09 | 1.172E-05 | 1.116E-05 | 4.586E-05 |
| RH=90% T=30°C | 3.638E-05 | 2.176E-07 | 7.687E-09 | 1.069E-05 | 1.828E-06 | 4.912E-05 |
| RH=90% T=90°C | 1.195E-05 | 7.148E-08 | 2.526E-09 | 1.577E-05 | 2.511E-05 | 5.290E-05 |

## 5.5 NITRIC ACID PRODUCTION IN THE 21-PWR WP

Radiolytic production of nitric acid in the 21-PWR WP for the time period between ten and one million years is determined from the energy deposition in the moist air filling the cavity of the WP and the G values of neutron and gamma radiation. The energy deposition rates by neutron and gamma radiation in the moist air in the lattice cell of the spent fuel rods in the central nine assemblies are calculated by MCNP. Four environment conditions are considered for the WP, all under one atmospheric pressure (Assumption 3.11). The conditions are the combinations of two relative humidities (40% and 90%) and two temperatures (30°C and 90°C). For each radiation source, there are 36 calculations each corresponding to a time step between ten and one million years.

The G values of 1.5 are used for both neutron and gamma (Assumptions 3.9 and 3.10) to determine the number of nitric acid molecules produced per second in the central nine assemblies of the WP. The results of this calculation can be scaled to compute production rate of other chemical species.

The nitric acid production rates per volume of moist air and per surface area of the fuel rods are computed from the G values and the energy depositions. Since the "f6" tally in MCNP is employed to score the energy depositions in units of MeV/g/s, the density of the moist air, the volume of the tally, and the total surface area of the fuel rods are needed. The density of the moist air for the four WP environments are presented in the worksheet "MoistAir2" of the Excel file "MoistAirProperties," which is included in the compact disk as Attachment III. The tally cell volume and the fuel rod surface area are computed below.

The volume of the unit cells outside the fuel rods in the central nine assemblies is:

$$(9)\ (208)\ (360.172)[(1.44272)^2 - \pi\ (0.5461)^2]\ \text{cm}^3$$
$$= 7.7170\text{E+5}\ \text{cm}^3.$$

The total surface area of the fuel rods is:

$$(9)\ (208)\ (360.172)(2\ \pi)(0.5461)\ \text{cm}^2$$
$$= 2.3135\text{E+6}\ \text{cm}^2.$$

# 6. RESULTS

The section presents the results of this calculation. The outputs of this calculation are reasonable compared to the inputs, and the results are suitable for the intended use. The uncertainties are taken into account by consistently using the most conservative approach; the calculations, therefore, yield a conservatively bounding set of results.

## 6.1 DOSE RATES AND ENERGY DEPOSITIONS BY GAMMA RAYS

Radiation dose rates and energy deposition rates by gamma radiation in the unit cells outside the fuel rods in the central nine SNF assemblies of the 21-PWR WP were calculated by MCNP and presented in Tables 15 and 16. The results were calculated for the four moist air conditions at 35 time steps spanning over one million years.

Table 15. Gamma Dose Rates (rad/h) Outside PWR SNF Rods

| Age (Years) | RH=40% T=90°C | RH=40% T=30°C | RH=90% T=30°C | RH=90% T=90°C |
|---|---|---|---|---|
| 10 | 7.81E+04 | 7.82E+04 | 7.82E+04 | 7.82E+04 |
| 15 | 5.75E+04 | 5.76E+04 | 5.76E+04 | 5.76E+04 |
| 20 | 4.69E+04 | 4.69E+04 | 4.69E+04 | 4.69E+04 |
| 25 | 4.02E+04 | 4.02E+04 | 4.02E+04 | 4.02E+04 |
| 35 | 3.04E+04 | 3.04E+04 | 3.04E+04 | 3.04E+04 |
| 50 | 2.10E+04 | 2.10E+04 | 2.10E+04 | 2.10E+04 |
| 70 | 1.31E+04 | 1.31E+04 | 1.31E+04 | 1.31E+04 |
| 100 | 6.51E+03 | 6.50E+03 | 6.50E+03 | 6.50E+03 |
| 150 | 2.05E+03 | 2.05E+03 | 2.05E+03 | 2.05E+03 |
| 200 | 6.46E+02 | 6.46E+02 | 6.46E+02 | 6.46E+02 |
| 250 | 2.07E+02 | 2.07E+02 | 2.07E+02 | 2.07E+02 |
| 350 | 2.51E+01 | 2.51E+01 | 2.51E+01 | 2.51E+01 |
| 500 | 5.47E+00 | 5.47E+00 | 5.47E+00 | 5.47E+00 |
| 700 | 4.59E+00 | 4.59E+00 | 4.59E+00 | 4.59E+00 |
| 1000 | 4.23E+00 | 4.23E+00 | 4.23E+00 | 4.23E+00 |
| 1500 | 4.02E+00 | 4.02E+00 | 4.02E+00 | 4.02E+00 |
| 2000 | 3.78E+00 | 3.78E+00 | 3.78E+00 | 3.78E+00 |
| 2500 | 3.71E+00 | 3.71E+00 | 3.71E+00 | 3.71E+00 |
| 3500 | 3.61E+00 | 3.61E+00 | 3.61E+00 | 3.61E+00 |
| 5000 | 3.49E+00 | 3.49E+00 | 3.49E+00 | 3.49E+00 |
| 7000 | 3.36E+00 | 3.36E+00 | 3.36E+00 | 3.36E+00 |
| 10000 | 3.22E+00 | 3.22E+00 | 3.22E+00 | 3.22E+00 |
| 15000 | 3.08E+00 | 3.08E+00 | 3.08E+00 | 3.08E+00 |
| 20000 | 3.00E+00 | 3.00E+00 | 3.00E+00 | 3.00E+00 |
| 25000 | 2.95E+00 | 2.95E+00 | 2.95E+00 | 2.95E+00 |
| 35000 | 2.99E+00 | 2.99E+00 | 2.99E+00 | 2.99E+00 |
| 50000 | 3.12E+00 | 3.12E+00 | 3.12E+00 | 3.12E+00 |
| 70000 | 3.34E+00 | 3.34E+00 | 3.34E+00 | 3.34E+00 |
| 100000 | 3.64E+00 | 3.64E+00 | 3.64E+00 | 3.64E+00 |
| 150000 | 3.95E+00 | 3.95E+00 | 3.95E+00 | 3.95E+00 |
| 200000 | 3.95E+00 | 3.95E+00 | 3.95E+00 | 3.95E+00 |
| 250000 | 3.80E+00 | 3.80E+00 | 3.80E+00 | 3.80E+00 |
| 350000 | 3.30E+00 | 3.30E+00 | 3.30E+00 | 3.30E+00 |
| 500000 | 2.56E+00 | 2.56E+00 | 2.56E+00 | 2.56E+00 |
| 700000 | 1.82E+00 | 1.82E+00 | 1.82E+00 | 1.82E+00 |
| 1000000 | 1.23E+00 | 1.23E+00 | 1.23E+00 | 1.23E+00 |

Table 16. Gamma Energy Deposition Rates (MeV/g/s ) Outside PWR SNF Rods

| Age (Years) | RH=40% T=90°C | RH=40% T=30°C | RH=90% T=30°C | RH=90% T=90°C |
|---|---|---|---|---|
| 10 | 1.06E+09 | 1.04E+09 | 1.05E+09 | 1.10E+09 |
| 15 | 7.81E+08 | 7.66E+08 | 7.67E+08 | 8.09E+08 |
| 20 | 6.35E+08 | 6.23E+08 | 6.23E+08 | 6.57E+08 |
| 25 | 5.43E+08 | 5.32E+08 | 5.33E+08 | 5.62E+08 |
| 35 | 4.09E+08 | 4.01E+08 | 4.02E+08 | 4.23E+08 |
| 50 | 2.82E+08 | 2.77E+08 | 2.77E+08 | 2.92E+08 |
| 70 | 1.76E+08 | 1.72E+08 | 1.72E+08 | 1.82E+08 |
| 100 | 8.75E+07 | 8.57E+07 | 8.58E+07 | 9.05E+07 |
| 150 | 2.76E+07 | 2.70E+07 | 2.71E+07 | 2.85E+07 |
| 200 | 8.68E+06 | 8.51E+06 | 8.52E+06 | 8.98E+06 |
| 250 | 2.78E+06 | 2.73E+06 | 2.73E+06 | 2.88E+06 |
| 350 | 3.31E+05 | 3.24E+05 | 3.24E+05 | 3.42E+05 |
| 500 | 6.69E+04 | 6.56E+04 | 6.57E+04 | 6.91E+04 |
| 700 | 5.65E+04 | 5.54E+04 | 5.55E+04 | 5.83E+04 |
| 1000 | 5.30E+04 | 5.20E+04 | 5.20E+04 | 5.48E+04 |
| 1500 | 5.15E+04 | 5.04E+04 | 5.05E+04 | 5.32E+04 |
| 2000 | 4.90E+04 | 4.80E+04 | 4.81E+04 | 5.06E+04 |
| 2500 | 4.84E+04 | 4.75E+04 | 4.75E+04 | 5.01E+04 |
| 3500 | 4.74E+04 | 4.64E+04 | 4.65E+04 | 4.90E+04 |
| 5000 | 4.60E+04 | 4.51E+04 | 4.52E+04 | 4.76E+04 |
| 7000 | 4.45E+04 | 4.36E+04 | 4.36E+04 | 4.60E+04 |
| 10000 | 4.30E+04 | 4.22E+04 | 4.22E+04 | 4.45E+04 |
| 15000 | 4.16E+04 | 4.07E+04 | 4.08E+04 | 4.30E+04 |
| 20000 | 4.08E+04 | 4.00E+04 | 4.00E+04 | 4.22E+04 |
| 25000 | 4.04E+04 | 3.96E+04 | 3.96E+04 | 4.18E+04 |
| 35000 | 4.11E+04 | 4.03E+04 | 4.04E+04 | 4.25E+04 |
| 50000 | 4.33E+04 | 4.24E+04 | 4.25E+04 | 4.48E+04 |
| 70000 | 4.66E+04 | 4.57E+04 | 4.57E+04 | 4.82E+04 |
| 100000 | 5.10E+04 | 5.00E+04 | 5.01E+04 | 5.28E+04 |
| 150000 | 5.56E+04 | 5.44E+04 | 5.45E+04 | 5.74E+04 |
| 200000 | 5.56E+04 | 5.45E+04 | 5.45E+04 | 5.75E+04 |
| 250000 | 5.35E+04 | 5.24E+04 | 5.25E+04 | 5.53E+04 |
| 350000 | 4.66E+04 | 4.56E+04 | 4.57E+04 | 4.81E+04 |
| 500000 | 3.60E+04 | 3.53E+04 | 3.54E+04 | 3.73E+04 |
| 700000 | 2.55E+04 | 2.50E+04 | 2.50E+04 | 2.64E+04 |
| 1000000 | 1.72E+04 | 1.68E+04 | 1.68E+04 | 1.77E+04 |

## 6.2 DOSE RATES AND ENERGY DEPOSITIONS BY NEUTRONS

Similar to the gamma results, dose rates and energy deposition rates by neutron radiation in the unit cells outside the fuel rods in the central nine SNF assemblies of the 21-PWR WP were calculated by MCNP and presented in Tables 17 and 18. The results were calculated for the four moist air conditions at 35 time steps spanning over one million years.

Table 17. Neutron Dose Rates (rad/h) Outside PWR SNF Rods

| Age (Years) | n/s/ass | n/s/WP | RH=40% T=90°C | RH=40% T=30°C | RH=90% T=30°C | RH=90% T=90°C |
|---|---|---|---|---|---|---|
| 10 | 3.4640E+08 | 7.2744E+09 | 3.5059E+00 | 3.5010E+00 | 3.5014E+00 | 3.5089E+00 |
| 15 | 2.8770E+08 | 6.0417E+09 | 2.9118E+00 | 2.9078E+00 | 2.9081E+00 | 2.9143E+00 |
| 20 | 2.3931E+08 | 5.0255E+09 | 2.4220E+00 | 2.4187E+00 | 2.4189E+00 | 2.4241E+00 |

Originator: JCT Date: 9/13/02 Checker: GR Date: 9/16/02

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 | 1.9933E+08 | 4.1859E+09 | 2.0174E+00 | 2.0146E+00 | 2.0148E+00 | 2.0191E+00 |
| 35 | 1.3899E+08 | 2.9188E+09 | 1.4067E+00 | 1.4048E+00 | 1.4049E+00 | 1.4079E+00 |
| 50 | 8.2570E+07 | 1.7340E+09 | 8.3569E-01 | 8.3453E-01 | 8.3462E-01 | 8.3640E-01 |
| 70 | 4.3246E+07 | 9.0817E+08 | 4.3769E-01 | 4.3708E-01 | 4.3713E-01 | 4.3806E-01 |
| 100 | 1.9766E+07 | 4.1509E+08 | 2.0005E-01 | 1.9977E-01 | 1.9979E-01 | 2.0022E-01 |
| 150 | 1.0018E+07 | 2.1038E+08 | 1.0139E-01 | 1.0125E-01 | 1.0126E-01 | 1.0148E-01 |
| 200 | 8.1960E+06 | 1.7212E+08 | 8.2951E-02 | 8.2836E-02 | 8.2845E-02 | 8.3022E-02 |
| 250 | 7.6199E+06 | 1.6002E+08 | 7.7121E-02 | 7.7014E-02 | 7.7022E-02 | 7.7187E-02 |
| 350 | 7.0603E+06 | 1.4827E+08 | 7.1457E-02 | 7.1358E-02 | 7.1365E-02 | 7.1518E-02 |
| 500 | 6.5264E+06 | 1.3705E+08 | 6.6054E-02 | 6.5962E-02 | 6.5969E-02 | 6.6110E-02 |
| 700 | 6.0621E+06 | 1.2730E+08 | 6.1354E-02 | 6.1269E-02 | 6.1276E-02 | 6.1407E-02 |
| 1000 | 5.5610E+06 | 1.1678E+08 | 5.6283E-02 | 5.6204E-02 | 5.6210E-02 | 5.6331E-02 |
| 1500 | 5.0051E+06 | 1.0511E+08 | 5.0656E-02 | 5.0586E-02 | 5.0591E-02 | 5.0700E-02 |
| 2000 | 4.6326E+06 | 9.7285E+07 | 4.6886E-02 | 4.6821E-02 | 4.6826E-02 | 4.6926E-02 |
| 2500 | 4.3403E+06 | 9.1146E+07 | 4.3928E-02 | 4.3867E-02 | 4.3872E-02 | 4.3966E-02 |
| 3500 | 3.8816E+06 | 8.1514E+07 | 3.9286E-02 | 3.9231E-02 | 3.9235E-02 | 3.9319E-02 |
| 5000 | 3.3339E+06 | 7.0012E+07 | 3.3742E-02 | 3.3695E-02 | 3.3699E-02 | 3.3771E-02 |
| 7000 | 2.7627E+06 | 5.8017E+07 | 2.7961E-02 | 2.7922E-02 | 2.7925E-02 | 2.7985E-02 |
| 10000 | 2.1410E+06 | 4.4961E+07 | 2.1669E-02 | 2.1639E-02 | 2.1641E-02 | 2.1687E-02 |
| 15000 | 1.5146E+06 | 3.1807E+07 | 1.5329E-02 | 1.5308E-02 | 1.5310E-02 | 1.5342E-02 |
| 20000 | 1.1779E+06 | 2.4736E+07 | 1.1921E-02 | 1.1905E-02 | 1.1906E-02 | 1.1932E-02 |
| 25000 | 9.9340E+05 | 2.0861E+07 | 1.0054E-02 | 1.0040E-02 | 1.0041E-02 | 1.0063E-02 |
| 35000 | 8.2520E+05 | 1.7329E+07 | 8.3518E-03 | 8.3402E-03 | 8.3411E-03 | 8.3589E-03 |
| 50000 | 7.4130E+05 | 1.5567E+07 | 7.5027E-03 | 7.4922E-03 | 7.4930E-03 | 7.5091E-03 |
| 70000 | 6.9530E+05 | 1.4601E+07 | 7.0371E-03 | 7.0273E-03 | 7.0281E-03 | 7.0431E-03 |
| 100000 | 6.4920E+05 | 1.3633E+07 | 6.5705E-03 | 6.5614E-03 | 6.5621E-03 | 6.5761E-03 |
| 150000 | 5.8910E+05 | 1.2371E+07 | 5.9623E-03 | 5.9540E-03 | 5.9546E-03 | 5.9673E-03 |
| 200000 | 5.3750E+05 | 1.1288E+07 | 5.4400E-03 | 5.4325E-03 | 5.4330E-03 | 5.4447E-03 |
| 250000 | 4.9203E+05 | 1.0333E+07 | 4.9798E-03 | 4.9729E-03 | 4.9734E-03 | 4.9841E-03 |
| 350000 | 4.1051E+05 | 8.6207E+06 | 4.1548E-03 | 4.1490E-03 | 4.1494E-03 | 4.1583E-03 |
| 500000 | 3.1361E+05 | 6.5858E+06 | 3.1740E-03 | 3.1696E-03 | 3.1700E-03 | 3.1767E-03 |
| 700000 | 2.2001E+05 | 4.6202E+06 | 2.2267E-03 | 2.2236E-03 | 2.2239E-03 | 2.2286E-03 |
| 1000000 | 1.3088E+05 | 2.7485E+06 | 1.3246E-03 | 1.3228E-03 | 1.3229E-03 | 1.3258E-03 |

Table 18. Neutron Energy Deposition Rates (MeV/g/s ) Outside PWR SNF Rods

| Age (Years) | n/s/ass | n/s/WP | RH=40% T=90°C | RH=40% T=30°C | RH=90% T=30°C | RH=90% T=90°C |
|---|---|---|---|---|---|---|
| 10 | 3.4640E+08 | 7.2744E+09 | 1.2995E+04 | 5.0720E+03 | 5.6575E+03 | 2.6684E+04 |
| 15 | 2.8770E+08 | 6.0417E+09 | 1.0793E+04 | 4.2125E+03 | 4.6988E+03 | 2.2162E+04 |
| 20 | 2.3931E+08 | 5.0255E+09 | 8.9774E+03 | 3.5040E+03 | 3.9085E+03 | 1.8435E+04 |
| 25 | 1.9933E+08 | 4.1859E+09 | 7.4776E+03 | 2.9186E+03 | 3.2555E+03 | 1.5355E+04 |
| 35 | 1.3899E+08 | 2.9188E+09 | 5.2140E+03 | 2.0351E+03 | 2.2700E+03 | 1.0707E+04 |
| 50 | 8.2570E+07 | 1.7340E+09 | 3.0975E+03 | 1.2090E+03 | 1.3486E+03 | 6.3606E+03 |
| 70 | 4.3246E+07 | 9.0817E+08 | 1.6223E+03 | 6.3321E+02 | 7.0631E+02 | 3.3313E+03 |
| 100 | 1.9766E+07 | 4.1509E+08 | 7.4149E+02 | 2.8942E+02 | 3.2282E+02 | 1.5226E+03 |
| 150 | 1.0018E+07 | 2.1038E+08 | 3.7581E+02 | 1.4668E+02 | 1.6362E+02 | 7.7171E+02 |
| 200 | 8.1960E+06 | 1.7212E+08 | 3.0746E+02 | 1.2001E+02 | 1.3386E+02 | 6.3136E+02 |
| 250 | 7.6199E+06 | 1.6002E+08 | 2.8585E+02 | 1.1157E+02 | 1.2445E+02 | 5.8698E+02 |
| 350 | 7.0603E+06 | 1.4827E+08 | 2.6486E+02 | 1.0338E+02 | 1.1531E+02 | 5.4387E+02 |
| 500 | 6.5264E+06 | 1.3705E+08 | 2.4483E+02 | 9.5560E+01 | 1.0659E+02 | 5.0274E+02 |
| 700 | 6.0621E+06 | 1.2730E+08 | 2.2741E+02 | 8.8762E+01 | 9.9008E+01 | 4.6698E+02 |
| 1000 | 5.5610E+06 | 1.1678E+08 | 2.0861E+02 | 8.1425E+01 | 9.0824E+01 | 4.2838E+02 |
| 1500 | 5.0051E+06 | 1.0511E+08 | 1.8776E+02 | 7.3285E+01 | 8.1745E+01 | 3.8555E+02 |
| 2000 | 4.6326E+06 | 9.7285E+07 | 1.7379E+02 | 6.7831E+01 | 7.5661E+01 | 3.5686E+02 |
| 2500 | 4.3403E+06 | 9.1146E+07 | 1.6282E+02 | 6.3551E+01 | 7.0887E+01 | 3.3434E+02 |
| 3500 | 3.8816E+06 | 8.1514E+07 | 1.4561E+02 | 5.6835E+01 | 6.3395E+01 | 2.9901E+02 |
| 5000 | 3.3339E+06 | 7.0012E+07 | 1.2507E+02 | 4.8815E+01 | 5.4450E+01 | 2.5682E+02 |

Originator: JT Date: 9/13/02 Checker: GR Date: 9/16/02

| | | | | | | |
|---|---|---|---|---|---|---|
| 7000 | 2.7627E+06 | 5.8017E+07 | 1.0364E+02 | 4.0452E+01 | 4.5121E+01 | 2.1282E+02 |
| 10000 | 2.1410E+06 | 4.4961E+07 | 8.0317E+01 | 3.1349E+01 | 3.4967E+01 | 1.6493E+02 |
| 15000 | 1.5146E+06 | 3.1807E+07 | 5.6818E+01 | 2.2177E+01 | 2.4737E+01 | 1.1667E+02 |
| 20000 | 1.1779E+06 | 2.4736E+07 | 4.4187E+01 | 1.7247E+01 | 1.9238E+01 | 9.0736E+01 |
| 25000 | 9.9340E+05 | 2.0861E+07 | 3.7266E+01 | 1.4545E+01 | 1.6224E+01 | 7.6524E+01 |
| 35000 | 8.2520E+05 | 1.7329E+07 | 3.0956E+01 | 1.2083E+01 | 1.3477E+01 | 6.3567E+01 |
| 50000 | 7.4130E+05 | 1.5567E+07 | 2.7809E+01 | 1.0854E+01 | 1.2107E+01 | 5.7104E+01 |
| 70000 | 6.9530E+05 | 1.4601E+07 | 2.6083E+01 | 1.0181E+01 | 1.1356E+01 | 5.3561E+01 |
| 100000 | 6.4920E+05 | 1.3633E+07 | 2.4354E+01 | 9.5057E+00 | 1.0603E+01 | 5.0009E+01 |
| 150000 | 5.8910E+05 | 1.2371E+07 | 2.2099E+01 | 8.6257E+00 | 9.6213E+00 | 4.5380E+01 |
| 200000 | 5.3750E+05 | 1.1288E+07 | 2.0164E+01 | 7.8701E+00 | 8.7786E+00 | 4.1405E+01 |
| 250000 | 4.9203E+05 | 1.0333E+07 | 1.8458E+01 | 7.2044E+00 | 8.0360E+00 | 3.7902E+01 |
| 350000 | 4.1051E+05 | 8.6207E+06 | 1.5400E+01 | 6.0107E+00 | 6.7046E+00 | 3.1623E+01 |
| 500000 | 3.1361E+05 | 6.5858E+06 | 1.1765E+01 | 4.5919E+00 | 5.1220E+00 | 2.4158E+01 |
| 700000 | 2.2001E+05 | 4.6202E+06 | 8.2534E+00 | 3.2214E+00 | 3.5933E+00 | 1.6948E+01 |
| 1000000 | 1.3088E+05 | 2.7485E+06 | 4.9098E+00 | 1.9164E+00 | 2.1376E+00 | 1.0082E+01 |

## 6.3 NITRIC ACID PRODUCTION IN THE 21-PWR WP

The gamma and neutron energy deposition rates in the unit cells presented in the previous section are used to determine the radiolytic production rates of nitric acid for the time period out to one million years. With the G values of 1.5 for both neutron and gamma radiation, production rates per moist air volume and per fuel rods surface area were determined. Tables 19 and 20 present the nitric acid production rates per volume at four moist air conditions for gamma rays and neutrons, respectively. Table 21 summarizes the maximum total production rates per moist air volume, which occur at the relative humidity of 40% and temperature of 30°C. Similarly, Table 22 gives the total production rates per surface area of the fuel rods. Results in Table 22 are graphically depicted in Figure 5. It is obvious that the total nitric production is dominated by gamma radiation and the production by neutron is negligible.

The results for nitric acid production can be extended to determine the production of other chemical species so long as G values are known. As a matter of fact, the yield of any particular chemical species is equal to its G value divided by 1.5 and multiplied by the yield.

Table 19. Nitric Acid Production Rate per Moist Air Volume (moleculesly/cm$^3$) by Gamma Rays

| Years | RH=40% T=90°C | RH=40% T=30°C | RH=90% T=30°C | RH=90% T=90°C |
|---|---|---|---|---|
| 10 | 4.3819E+17 | 5.7144E+17 | 5.6721E+17 | 3.8751E+17 |
| 15 | 3.2157E+17 | 4.1943E+17 | 4.1635E+17 | 2.8441E+17 |
| 20 | 2.6147E+17 | 3.4076E+17 | 3.3826E+17 | 2.3108E+17 |
| 25 | 2.2350E+17 | 2.9129E+17 | 2.8915E+17 | 1.9753E+17 |
| 35 | 1.6846E+17 | 2.1950E+17 | 2.1789E+17 | 1.4885E+17 |
| 50 | 1.1619E+17 | 1.5135E+17 | 1.5023E+17 | 1.0263E+17 |
| 70 | 7.2333E+16 | 9.4230E+16 | 9.3540E+16 | 6.3898E+16 |
| 100 | 3.6028E+16 | 4.6913E+16 | 4.6569E+16 | 3.1812E+16 |
| 150 | 1.1356E+16 | 1.4793E+16 | 1.4685E+16 | 1.0031E+16 |
| 200 | 3.5734E+15 | 4.6551E+15 | 4.6210E+15 | 3.1567E+15 |
| 250 | 1.1453E+15 | 1.4918E+15 | 1.4808E+15 | 1.0116E+15 |
| 350 | 1.3606E+14 | 1.7727E+14 | 1.7596E+14 | 1.2015E+14 |
| 500 | 2.7550E+13 | 3.5914E+13 | 3.5651E+13 | 2.4301E+13 |
| 700 | 2.3251E+13 | 3.0310E+13 | 3.0088E+13 | 2.0510E+13 |
| 1000 | 2.1822E+13 | 2.8440E+13 | 2.8230E+13 | 1.9258E+13 |

| | | | | |
|---|---|---|---|---|
| 1500 | 2.1186E+13 | 2.7605E+13 | 2.7402E+13 | 1.8704E+13 |
| 2000 | 2.0172E+13 | 2.6281E+13 | 2.6088E+13 | 1.7812E+13 |
| 2500 | 1.9943E+13 | 2.5981E+13 | 2.5789E+13 | 1.7611E+13 |
| 3500 | 1.9499E+13 | 2.5401E+13 | 2.5214E+13 | 1.7219E+13 |
| 5000 | 1.8952E+13 | 2.4690E+13 | 2.4508E+13 | 1.6737E+13 |
| 7000 | 1.8310E+13 | 2.3851E+13 | 2.3676E+13 | 1.6171E+13 |
| 10000 | 1.7709E+13 | 2.3069E+13 | 2.2899E+13 | 1.5640E+13 |
| 15000 | 1.7106E+13 | 2.2284E+13 | 2.2120E+13 | 1.5108E+13 |
| 20000 | 1.6792E+13 | 2.1874E+13 | 2.1713E+13 | 1.4832E+13 |
| 25000 | 1.6626E+13 | 2.1659E+13 | 2.1500E+13 | 1.4685E+13 |
| 35000 | 1.6934E+13 | 2.2060E+13 | 2.1898E+13 | 1.4958E+13 |
| 50000 | 1.7832E+13 | 2.3227E+13 | 2.3057E+13 | 1.5751E+13 |
| 70000 | 1.9189E+13 | 2.4992E+13 | 2.4808E+13 | 1.6949E+13 |
| 100000 | 2.1008E+13 | 2.7362E+13 | 2.7161E+13 | 1.8556E+13 |
| 150000 | 2.2875E+13 | 2.9793E+13 | 2.9574E+13 | 2.0204E+13 |
| 200000 | 2.2886E+13 | 2.9807E+13 | 2.9589E+13 | 2.0214E+13 |
| 250000 | 2.2033E+13 | 2.8696E+13 | 2.8486E+13 | 1.9460E+13 |
| 350000 | 1.9166E+13 | 2.4963E+13 | 2.4780E+13 | 1.6928E+13 |
| 500000 | 1.4837E+13 | 1.9325E+13 | 1.9183E+13 | 1.3104E+13 |
| 700000 | 1.0507E+13 | 1.3686E+13 | 1.3586E+13 | 9.2808E+12 |
| 1000000 | 7.0654E+12 | 9.2030E+12 | 9.1354E+12 | 6.2403E+12 |

Table 20. Nitric Acid Production Rate per Moist Air Volume (moleculeslylcm$^3$) by Neutrons

| Years | RH=40% T=90°C | RH=40% T=30°C | RH=90% T=30°C | RH=90% T=90°C |
|---|---|---|---|---|
| 10 | 5.3491E+12 | 2.7760E+12 | 3.0696E+12 | 9.3849E+12 |
| 15 | 4.4427E+12 | 2.3056E+12 | 2.5495E+12 | 7.7946E+12 |
| 20 | 3.6954E+12 | 1.9178E+12 | 2.1206E+12 | 6.4835E+12 |
| 25 | 3.0781E+12 | 1.5974E+12 | 1.7664E+12 | 5.4004E+12 |
| 35 | 2.1463E+12 | 1.1138E+12 | 1.2317E+12 | 3.7656E+12 |
| 50 | 1.2751E+12 | 6.6169E+11 | 7.3170E+11 | 2.2370E+12 |
| 70 | 6.6781E+11 | 3.4656E+11 | 3.8322E+11 | 1.1716E+12 |
| 100 | 3.0523E+11 | 1.5840E+11 | 1.7516E+11 | 5.3551E+11 |
| 150 | 1.5470E+11 | 8.0282E+10 | 8.8775E+10 | 2.7141E+11 |
| 200 | 1.2656E+11 | 6.5681E+10 | 7.2629E+10 | 2.2205E+11 |
| 250 | 1.1767E+11 | 6.1064E+10 | 6.7524E+10 | 2.0644E+11 |
| 350 | 1.0903E+11 | 5.6579E+10 | 6.2565E+10 | 1.9128E+11 |
| 500 | 1.0078E+11 | 5.2301E+10 | 5.7834E+10 | 1.7682E+11 |
| 700 | 9.3611E+10 | 4.8580E+10 | 5.3719E+10 | 1.6424E+11 |
| 1000 | 8.5873E+10 | 4.4564E+10 | 4.9279E+10 | 1.5066E+11 |
| 1500 | 7.7289E+10 | 4.0110E+10 | 4.4353E+10 | 1.3560E+11 |
| 2000 | 7.1537E+10 | 3.7124E+10 | 4.1052E+10 | 1.2551E+11 |
| 2500 | 6.7023E+10 | 3.4782E+10 | 3.8462E+10 | 1.1759E+11 |
| 3500 | 5.9940E+10 | 3.1106E+10 | 3.4397E+10 | 1.0516E+11 |
| 5000 | 5.1482E+10 | 2.6717E+10 | 2.9543E+10 | 9.0324E+10 |
| 7000 | 4.2662E+10 | 2.2140E+10 | 2.4482E+10 | 7.4849E+10 |
| 10000 | 3.3061E+10 | 1.7157E+10 | 1.8972E+10 | 5.8005E+10 |
| 15000 | 2.3389E+10 | 1.2138E+10 | 1.3422E+10 | 4.1035E+10 |
| 20000 | 1.8189E+10 | 9.4394E+09 | 1.0438E+10 | 3.1912E+10 |
| 25000 | 1.5340E+10 | 7.9608E+09 | 8.8030E+09 | 2.6914E+10 |
| 35000 | 1.2743E+10 | 6.6129E+09 | 7.3125E+09 | 2.2357E+10 |
| 50000 | 1.1447E+10 | 5.9406E+09 | 6.5690E+09 | 2.0084E+10 |
| 70000 | 1.0737E+10 | 5.5720E+09 | 6.1614E+09 | 1.8838E+10 |
| 100000 | 1.0025E+10 | 5.2025E+09 | 5.7529E+09 | 1.7589E+10 |
| 150000 | 9.0969E+09 | 4.7209E+09 | 5.2203E+09 | 1.5960E+10 |
| 200000 | 8.3001E+09 | 4.3074E+09 | 4.7631E+09 | 1.4562E+10 |
| 250000 | 7.5980E+09 | 3.9430E+09 | 4.3601E+09 | 1.3330E+10 |
| 350000 | 6.3391E+09 | 3.2897E+09 | 3.6377E+09 | 1.1122E+10 |
| 500000 | 4.8428E+09 | 2.5132E+09 | 2.7791E+09 | 8.4965E+09 |
| 700000 | 3.3974E+09 | 1.7631E+09 | 1.9496E+09 | 5.9607E+09 |
| 1000000 | 2.0211E+09 | 1.0488E+09 | 1.1598E+09 | 3.5459E+09 |

Table 21. Nitric Acid Production Rate per Volume (molecules/y/cm$^3$) at 40% RH and 30°C

| Years | Gammas | Neutrons | Total |
|---|---|---|---|
| 10 | 5.7144E+17 | 2.7760E+12 | 5.7145E+17 |
| 15 | 4.1943E+17 | 2.3056E+12 | 4.1943E+17 |
| 20 | 3.4076E+17 | 1.9178E+12 | 3.4076E+17 |
| 25 | 2.9129E+17 | 1.5974E+12 | 2.9129E+17 |
| 35 | 2.1950E+17 | 1.1138E+12 | 2.1950E+17 |
| 50 | 1.5135E+17 | 6.6169E+11 | 1.5135E+17 |
| 70 | 9.4230E+16 | 3.4656E+11 | 9.4230E+16 |
| 100 | 4.6913E+16 | 1.5840E+11 | 4.6913E+16 |
| 150 | 1.4793E+16 | 8.0282E+10 | 1.4793E+16 |
| 200 | 4.6551E+15 | 6.5681E+10 | 4.6552E+15 |
| 250 | 1.4918E+15 | 6.1064E+10 | 1.4919E+15 |
| 350 | 1.7727E+14 | 5.6579E+10 | 1.7732E+14 |
| 500 | 3.5914E+13 | 5.2301E+10 | 3.5967E+13 |
| 700 | 3.0310E+13 | 4.8580E+10 | 3.0358E+13 |
| 1000 | 2.8440E+13 | 4.4564E+10 | 2.8484E+13 |
| 1500 | 2.7605E+13 | 4.0110E+10 | 2.7645E+13 |
| 2000 | 2.6281E+13 | 3.7124E+10 | 2.6318E+13 |
| 2500 | 2.5981E+13 | 3.4782E+10 | 2.6015E+13 |
| 3500 | 2.5401E+13 | 3.1106E+10 | 2.5432E+13 |
| 5000 | 2.4690E+13 | 2.6717E+10 | 2.4716E+13 |
| 7000 | 2.3851E+13 | 2.2140E+10 | 2.3873E+13 |
| 10000 | 2.3069E+13 | 1.7157E+10 | 2.3086E+13 |
| 15000 | 2.2284E+13 | 1.2138E+10 | 2.2296E+13 |
| 20000 | 2.1874E+13 | 9.4394E+09 | 2.1883E+13 |
| 25000 | 2.1659E+13 | 7.9608E+09 | 2.1667E+13 |
| 35000 | 2.2060E+13 | 6.6129E+09 | 2.2066E+13 |
| 50000 | 2.3227E+13 | 5.9406E+09 | 2.3233E+13 |
| 70000 | 2.4992E+13 | 5.5720E+09 | 2.4997E+13 |
| 100000 | 2.7362E+13 | 5.2025E+09 | 2.7367E+13 |
| 150000 | 2.9793E+13 | 4.7209E+09 | 2.9797E+13 |
| 200000 | 2.9807E+13 | 4.3074E+09 | 2.9812E+13 |
| 250000 | 2.8696E+13 | 3.9430E+09 | 2.8700E+13 |
| 350000 | 2.4963E+13 | 3.2897E+09 | 2.4967E+13 |
| 500000 | 1.9325E+13 | 2.5132E+09 | 1.9327E+13 |
| 700000 | 1.3686E+13 | 1.7631E+09 | 1.3688E+13 |
| 1000000 | 9.2030E+12 | 1.0488E+09 | 9.2040E+12 |

Table 22. Nitric Acid Production Rate per Fuel Rod Area (molecules/y/cm$^2$) at 40% RH and 30°C

| Years | Gammas | Neutrons | Total |
|---|---|---|---|
| 10 | 1.9061E+17 | 9.2596E+11 | 1.9061E+17 |
| 15 | 1.3991E+17 | 7.6905E+11 | 1.3991E+17 |
| 20 | 1.1366E+17 | 6.3970E+11 | 1.1367E+17 |
| 25 | 9.7163E+16 | 5.3283E+11 | 9.7164E+16 |
| 35 | 7.3218E+16 | 3.7153E+11 | 7.3219E+16 |
| 50 | 5.0484E+16 | 2.2072E+11 | 5.0484E+16 |
| 70 | 3.1432E+16 | 1.1560E+11 | 3.1432E+16 |
| 100 | 1.5648E+16 | 5.2836E+10 | 1.5649E+16 |
| 150 | 4.9345E+15 | 2.6779E+10 | 4.9345E+15 |
| 200 | 1.5528E+15 | 2.1909E+10 | 1.5528E+15 |
| 250 | 4.9761E+14 | 2.0369E+10 | 4.9763E+14 |
| 350 | 5.9130E+13 | 1.8873E+10 | 5.9149E+13 |
| 500 | 1.1980E+13 | 1.7446E+10 | 1.1997E+13 |
| 700 | 1.0110E+13 | 1.6205E+10 | 1.0126E+13 |

| | | | |
|---|---|---|---|
| 1000 | 9.4865E+12 | 1.4865E+10 | 9.5013E+12 |
| 1500 | 9.2081E+12 | 1.3379E+10 | 9.2214E+12 |
| 2000 | 8.7664E+12 | 1.2383E+10 | 8.7788E+12 |
| 2500 | 8.6662E+12 | 1.1602E+10 | 8.6778E+12 |
| 3500 | 8.4729E+12 | 1.0376E+10 | 8.4833E+12 |
| 5000 | 8.2356E+12 | 8.9118E+09 | 8.2445E+12 |
| 7000 | 7.9559E+12 | 7.3850E+09 | 7.9633E+12 |
| 10000 | 7.6950E+12 | 5.7231E+09 | 7.7007E+12 |
| 15000 | 7.4332E+12 | 4.0487E+09 | 7.4372E+12 |
| 20000 | 7.2963E+12 | 3.1486E+09 | 7.2994E+12 |
| 25000 | 7.2245E+12 | 2.6555E+09 | 7.2272E+12 |
| 35000 | 7.3583E+12 | 2.2058E+09 | 7.3605E+12 |
| 50000 | 7.7477E+12 | 1.9816E+09 | 7.7497E+12 |
| 70000 | 8.3363E+12 | 1.8586E+09 | 8.3382E+12 |
| 100000 | 9.1268E+12 | 1.7354E+09 | 9.1286E+12 |
| 150000 | 9.9378E+12 | 1.5747E+09 | 9.9393E+12 |
| 200000 | 9.9427E+12 | 1.4368E+09 | 9.9441E+12 |
| 250000 | 9.5721E+12 | 1.3152E+09 | 9.5734E+12 |
| 350000 | 8.3268E+12 | 1.0973E+09 | 8.3279E+12 |
| 500000 | 6.4461E+12 | 8.3831E+08 | 6.4469E+12 |
| 700000 | 4.5651E+12 | 5.8811E+08 | 4.5657E+12 |
| 1000000 | 3.0698E+12 | 3.4985E+08 | 3.0701E+12 |

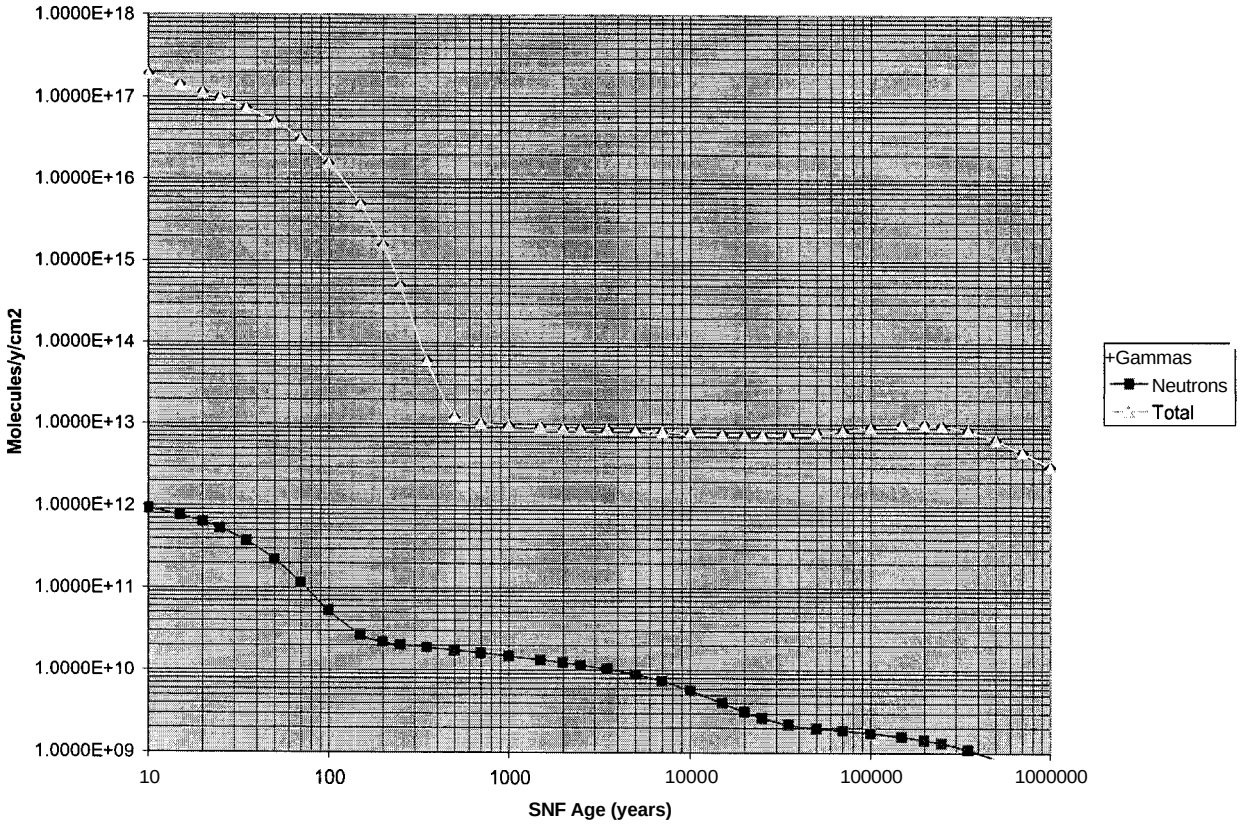



Figure 5. Nitric Acid Production Rate per Fuel Rod Area

## 6.4 THERMAL POWER OF THE AVERAGE PWR SNF ASSEMBLY

The thermal power (decay heat rate) of the average PWR SNF assembly for the time period between one and one million years are obtained from the file Waste.Stream.E5.R1.B9.cut in disk 3 of 5 (CRWMS M&O 1999c), and presented in Table 23. Figure 6 graphically displays the data in the table.

The thermal power is comprised of three components, the light elements, the actinides, and the fission products. The light elements come fiom the incore spacers and grid supports; the heat of the light elements is basically due to gamma and beta decays of the radioactive elements. The biggest contributor is the $Co^{60}$ isotope, which has a half-life of 5.27 years (Parrington et al. 1996, p. 25). The actinides are produced transmutation and decay of the heavy isotopes. The heat of the actinides comes from alpha, beta, and gamma decays and even neutrons from spontaneous fission. The fission products are the results of the nuclear fission process. The heat of the fission products is fiom gamma and beta decays. The major contributors to decay heat from this component are the $Sr^{90}$-$Y^{90}$ and the $Cs^{137}$-$Ba^{137}$ pairs. The first pair emits betas and the second pair emits gammas. $Sr^{90}$ has a half-life of 28.78 years and $Cs^{137}$ has a half-life of 30.07 years (Parrington et al. 1996, pp. 29 and 34).

It is evident from Figure 6 that for the first 60 years the thermal power from the fission products is the dominant component. After this time, decay heat from the actinides is orders of magnitude larger than the other two components.

Table 23. Thermal Power (watts) of the Average PWR SNF Assembly to One Million Years

| Age (years) | Light Elements | Actinides | Fission Products | Total/Assembly | Total/WP |
|---|---|---|---|---|---|
| 1 | 1.0000E+02 | 5.1600E+02 | 5.0400E+03 | 5.6560E+03 | 1.1878E+05 |
| 2 | 8.1100E+01 | 2.9600E+02 | 2.8000E+03 | 3.1771E+03 | 6.6719E+04 |
| 3 | 7.0500E+01 | 2.4900E+02 | 1.8100E+03 | 2.1295E+03 | 4.4720E+04 |
| 4 | 6.1600E+01 | 2.3800E+02 | 1.3000E+03 | 1.5996E+03 | 3.3592E+04 |
| 5 | 5.3900E+01 | 2.3400E+02 | 1.0300E+03 | 1.3179E+03 | 2.7676E+04 |
| 6 | 4.7100E+01 | 2.3300E+02 | 8.6600E+02 | 1.1461E+03 | 2.4068E+04 |
| 7 | 4.1300E+01 | 2.3100E+02 | 7.6700E+02 | 1.0393E+03 | 2.1825E+04 |
| 8 | 3.6100E+01 | 2.3000E+02 | 7.0000E+02 | 9.6610E+02 | 2.0288E+04 |
| 9 | 3.1700E+01 | 2.2800E+02 | 6.5300E+02 | 9.1270E+02 | 1.9167E+04 |
| 10 | 2.7700E+01 | 2.2700E+02 | 6.1700E+02 | 8.7170E+02 | 1.8306E+04 |
| 11 | 2.4300E+01 | 2.2600E+02 | 5.8800E+02 | 8.3830E+02 | 1.7604E+04 |
| 12 | 2.1300E+01 | 2.2400E+02 | 5.6400E+02 | 8.0930E+02 | 1.6995E+04 |
| 13 | 1.8700E+01 | 2.2300E+02 | 5.4300E+02 | 7.8470E+02 | 1.6479E+04 |
| 14 | 1.6400E+01 | 2.2200E+02 | 5.2500E+02 | 7.6340E+02 | 1.6031E+04 |
| 15 | 1.4300E+01 | 2.2000E+02 | 5.0800E+02 | 7.4230E+02 | 1.5588E+04 |
| 16 | 1.2600E+01 | 2.1900E+02 | 4.9300E+02 | 7.2460E+02 | 1.5217E+04 |
| 17 | 1.1000E+01 | 2.1800E+02 | 4.7900E+02 | 7.0800E+02 | 1.4868E+04 |
| 18 | 9.6600E+00 | 2.1600E+02 | 4.6600E+02 | 6.9166E+02 | 1.4525E+04 |
| 19 | 8.4700E+00 | 2.1500E+02 | 4.5400E+02 | 6.7747E+02 | 1.4227E+04 |
| 20 | 7.4300E+00 | 2.1400E+02 | 4.4200E+02 | 6.6343E+02 | 1.3932E+04 |
| 21 | 6.5200E+00 | 2.1200E+02 | 4.3000E+02 | 6.4852E+02 | 1.3619E+04 |
| 22 | 5.7200E+00 | 2.1100E+02 | 4.1900E+02 | 6.3572E+02 | 1.3350E+04 |
| 23 | 5.0100E+00 | 2.1000E+02 | 4.0900E+02 | 6.2401E+02 | 1.3104E+04 |
| 24 | 4.4000E+00 | 2.0900E+02 | 3.9900E+02 | 6.1240E+02 | 1.2860E+04 |
| 25 | 3.8600E+00 | 2.0700E+02 | 3.8900E+02 | 5.9986E+02 | 1.2597E+04 |
| 26 | 3.3900E+00 | 2.0600E+02 | 3.7900E+02 | 5.8839E+02 | 1.2356E+04 |

| | | | | | |
|---|---|---|---|---|---|
| 27 | 2.9700E+00 | 2.0500E+02 | 3.7000E+02 | 5.7797E+02 | 1.2137E+04 |
| 28 | 2.6100E+00 | 2.0400E+02 | 3.6100E+02 | 5.6761E+02 | 1.1920E+04 |
| 29 | 2.2900E+00 | 2.0200E+02 | 3.5200E+02 | 5.5629E+02 | 1.1682E+04 |
| 30 | 2.0100E+00 | 2.0100E+02 | 3.4300E+02 | 5.4601E+02 | 1.1466E+04 |
| 31 | 1.7700E+00 | 2.0000E+02 | 3.3500E+02 | 5.3677E+02 | 1.1272E+04 |
| 32 | 1.5500E+00 | 1.9900E+02 | 3.2700E+02 | 5.2755E+02 | 1.1079E+04 |
| 33 | 1.3600E+00 | 1.9800E+02 | 3.1900E+02 | 5.1836E+02 | 1.0886E+04 |
| 34 | 1.2000E+00 | 1.9700E+02 | 3.1100E+02 | 5.0920E+02 | 1.0693E+04 |
| 35 | 1.0500E+00 | 1.9500E+02 | 3.0300E+02 | 4.9905E+02 | 1.0480E+04 |
| 36 | 9.2800E-01 | 1.9400E+02 | 2.9600E+02 | 4.9093E+02 | 1.0309E+04 |
| 37 | 8.1600E-01 | 1.9300E+02 | 2.8900E+02 | 4.8282E+02 | 1.0139E+04 |
| 38 | 7.1900E-01 | 1.9200E+02 | 2.8200E+02 | 4.7472E+02 | 9.9691E+03 |
| 39 | 6.3300E-01 | 1.9100E+02 | 2.7500E+02 | 4.6663E+02 | 9.7993E+03 |
| 40 | 5.5800E-01 | 1.9000E+02 | 2.6900E+02 | 4.5956E+02 | 9.6507E+03 |
| 41 | 4.9300E-01 | 1.8900E+02 | 2.6200E+02 | 4.5149E+02 | 9.4814E+03 |
| 42 | 4.3500E-01 | 1.8800E+02 | 2.5600E+02 | 4.4444E+02 | 9.3331E+03 |
| 43 | 3.8400E-01 | 1.8700E+02 | 2.5000E+02 | 4.3738E+02 | 9.1851E+03 |
| 44 | 3.4000E-01 | 1.8600E+02 | 2.4400E+02 | 4.3034E+02 | 9.0371E+03 |
| 45 | 3.0100E-01 | 1.8500E+02 | 2.3800E+02 | 4.2330E+02 | 8.8893E+03 |
| 46 | 2.6700E-01 | 1.8400E+02 | 2.3200E+02 | 4.1627E+02 | 8.7416E+03 |
| 47 | 2.3700E-01 | 1.8300E+02 | 2.2700E+02 | 4.1024E+02 | 8.6150E+03 |
| 48 | 2.1100E-01 | 1.8200E+02 | 2.2100E+02 | 4.0321E+02 | 8.4674E+03 |
| 49 | 1.8800E-01 | 1.8100E+02 | 2.1600E+02 | 3.9719E+02 | 8.3409E+03 |
| 50 | 1.6700E-01 | 1.8000E+02 | 2.1100E+02 | 3.9117E+02 | 8.2145E+03 |
| 51 | 1.5000E-01 | 1.7900E+02 | 2.0600E+02 | 3.8515E+02 | 8.0882E+03 |
| 52 | 1.3400E-01 | 1.7800E+02 | 2.0100E+02 | 3.7913E+02 | 7.9618E+03 |
| 53 | 1.2000E-01 | 1.7700E+02 | 1.9600E+02 | 3.7312E+02 | 7.8355E+03 |
| 54 | 1.0800E-01 | 1.7600E+02 | 1.9100E+02 | 3.6711E+02 | 7.7093E+03 |
| 55 | 9.7700E-02 | 1.7500E+02 | 1.8700E+02 | 3.6210E+02 | 7.6041E+03 |
| 56 | 8.8400E-02 | 1.7400E+02 | 1.8300E+02 | 3.5709E+02 | 7.4989E+03 |
| 57 | 8.0300E-02 | 1.7300E+02 | 1.7800E+02 | 3.5108E+02 | 7.3727E+03 |
| 58 | 7.3100E-02 | 1.7300E+02 | 1.7400E+02 | 3.4707E+02 | 7.2885E+03 |
| 59 | 6.6800E-02 | 1.7200E+02 | 1.7000E+02 | 3.4207E+02 | 7.1834E+03 |
| 60 | 6.1300E-02 | 1.7100E+02 | 1.6600E+02 | 3.3706E+02 | 7.0783E+03 |
| 61 | 5.6400E-02 | 1.7000E+02 | 1.6200E+02 | 3.3206E+02 | 6.9732E+03 |
| 62 | 5.2100E-02 | 1.6900E+02 | 1.5800E+02 | 3.2705E+02 | 6.8681E+03 |
| 63 | 4.8400E-02 | 1.6800E+02 | 1.5400E+02 | 3.2205E+02 | 6.7630E+03 |
| 64 | 4.5100E-02 | 1.6800E+02 | 1.5100E+02 | 3.1905E+02 | 6.6999E+03 |
| 65 | 4.2100E-02 | 1.6700E+02 | 1.4700E+02 | 3.1404E+02 | 6.5949E+03 |
| 66 | 3.9600E-02 | 1.6600E+02 | 1.4400E+02 | 3.1004E+02 | 6.5108E+03 |
| 67 | 3.7300E-02 | 1.6500E+02 | 1.4000E+02 | 3.0504E+02 | 6.4058E+03 |
| 68 | 3.5300E-02 | 1.6400E+02 | 1.3700E+02 | 3.0104E+02 | 6.3217E+03 |
| 69 | 3.3500E-02 | 1.6400E+02 | 1.3400E+02 | 2.9803E+02 | 6.2587E+03 |
| 70 | 3.2000E-02 | 1.6300E+02 | 1.3000E+02 | 2.9303E+02 | 6.1537E+03 |
| 71 | 3.0600E-02 | 1.6200E+02 | 1.2700E+02 | 2.8903E+02 | 6.0696E+03 |
| 72 | 2.9300E-02 | 1.6200E+02 | 1.2400E+02 | 2.8603E+02 | 6.0066E+03 |
| 73 | 2.8300E-02 | 1.6100E+02 | 1.2100E+02 | 2.8203E+02 | 5.9226E+03 |
| 74 | 2.7300E-02 | 1.6000E+02 | 1.1900E+02 | 2.7903E+02 | 5.8596E+03 |
| 75 | 2.6400E-02 | 1.5900E+02 | 1.1600E+02 | 2.7503E+02 | 5.7756E+03 |
| 76 | 2.5700E-02 | 1.5900E+02 | 1.1300E+02 | 2.7203E+02 | 5.7125E+03 |
| 77 | 2.5000E-02 | 1.5800E+02 | 1.1000E+02 | 2.6803E+02 | 5.6285E+03 |
| 78 | 2.4400E-02 | 1.5700E+02 | 1.0800E+02 | 2.6502E+02 | 5.5655E+03 |
| 79 | 2.3800E-02 | 1.5700E+02 | 1.0500E+02 | 2.6202E+02 | 5.5025E+03 |
| 80 | 2.3300E-02 | 1.5600E+02 | 1.0300E+02 | 2.5902E+02 | 5.4395E+03 |
| 81 | 2.2900E-02 | 1.5500E+02 | 1.0000E+02 | 2.5502E+02 | 5.3555E+03 |
| 82 | 2.2500E-02 | 1.5500E+02 | 9.8000E+01 | 2.5302E+02 | 5.3135E+03 |
| 83 | 2.2100E-02 | 1.5400E+02 | 9.5700E+01 | 2.4972E+02 | 5.2442E+03 |
| 84 | 2.1800E-02 | 1.5300E+02 | 9.3400E+01 | 2.4642E+02 | 5.1749E+03 |

| | | | | | |
|---|---|---|---|---|---|
| 85 | 2.1500E-02 | 1.5300E+02 | 9.1200E+01 | 2.4422E+02 | 5.1287E+03 |
| 86 | 2.1200E-02 | 1.5200E+02 | 8.9100E+01 | 2.4112E+02 | 5.0635E+03 |
| 87 | 2.0900E-02 | 1.5200E+02 | 8.7000E+01 | 2.3902E+02 | 5.0194E+03 |
| 88 | 2.0700E-02 | 1.5100E+02 | 8.4900E+01 | 2.3592E+02 | 4.9543E+03 |
| 89 | 2.0500E-02 | 1.5000E+02 | 8.2900E+01 | 2.3292E+02 | 4.8913E+03 |
| 90 | 2.0300E-02 | 1.5000E+02 | 8.1000E+01 | 2.3102E+02 | 4.8514E+03 |
| 91 | 2.0100E-02 | 1.4900E+02 | 7.9100E+01 | 2.2812E+02 | 4.7905E+03 |
| 92 | 1.9900E-02 | 1.4900E+02 | 7.7200E+01 | 2.2622E+02 | 4.7506E+03 |
| 93 | 1.9800E-02 | 1.4800E+02 | 7.5400E+01 | 2.2342E+02 | 4.6918E+03 |
| 94 | 1.9600E-02 | 1.4700E+02 | 7.3600E+01 | 2.2062E+02 | 4.6330E+03 |
| 95 | 1.9500E-02 | 1.4700E+02 | 7.1900E+01 | 2.1892E+02 | 4.5973E+03 |
| 96 | 1.9400E-02 | 1.4600E+02 | 7.0200E+01 | 2.1622E+02 | 4.5406E+03 |
| 97 | 1.9200E-02 | 1.4600E+02 | 6.8500E+01 | 2.1452E+02 | 4.5049E+03 |
| 98 | 1.9100E-02 | 1.4500E+02 | 6.6900E+01 | 2.1192E+02 | 4.4503E+03 |
| 99 | 1.9000E-02 | 1.4500E+02 | 6.5400E+01 | 2.1042E+02 | 4.4188E+03 |
| 100 | 1.8900E-02 | 1.4400E+02 | 6.3800E+01 | 2.0782E+02 | 4.3642E+03 |
| 110 | 1.7900E-02 | 1.3900E+02 | 5.0300E+01 | 1.8932E+02 | 3.9757E+03 |
| 120 | 1.7100E-02 | 1.3400E+02 | 3.9700E+01 | 1.7372E+02 | 3.6481E+03 |
| 130 | 1.6500E-02 | 1.3000E+02 | 3.1300E+01 | 1.6132E+02 | 3.3876E+03 |
| 140 | 1.5800E-02 | 1.2600E+02 | 2.4700E+01 | 1.5072E+02 | 3.1650E+03 |
| 150 | 1.5200E-02 | 1.2200E+02 | 1.9400E+01 | 1.4142E+02 | 2.9697E+03 |
| 160 | 1.4700E-02 | 1.1900E+02 | 1.5300E+01 | 1.3431E+02 | 2.8206E+03 |
| 170 | 1.4200E-02 | 1.1500E+02 | 1.2100E+01 | 1.2711E+02 | 2.6694E+03 |
| 180 | 1.3700E-02 | 1.1200E+02 | 9.5400E+00 | 1.2155E+02 | 2.5526E+03 |
| 190 | 1.3300E-02 | 1.0900E+02 | 7.5300E+00 | 1.1654E+02 | 2.4474E+03 |
| 200 | 1.2900E-02 | 1.0700E+02 | 5.9400E+00 | 1.1295E+02 | 2.3720E+03 |
| 250 | 1.1200E-02 | 9.4900E+01 | 1.8200E+00 | 9.6731E+01 | 2.0314E+03 |
| 300 | 1.0100E-02 | 8.5600E+01 | 5.6800E-01 | 8.6178E+01 | 1.8097E+03 |
| 350 | 9.2200E-03 | 7.8000E+01 | 1.8300E-01 | 7.8192E+01 | 1.6420E+03 |
| 400 | 8.6300E-03 | 7.1700E+01 | 6.4800E-02 | 7.1773E+01 | 1.5072E+03 |
| 450 | 8.2100E-03 | 6.6400E+01 | 2.8400E-02 | 6.6437E+01 | 1.3952E+03 |
| 500 | 7.9100E-03 | 6.1700E+01 | 1.7000E-02 | 6.1725E+01 | 1.2962E+03 |
| 550 | 7.6900E-03 | 5.7700E+01 | 1.3400E-02 | 5.7721E+01 | 1.2121E+03 |
| 600 | 7.5300E-03 | 5.4100E+01 | 1.2200E-02 | 5.4120E+01 | 1.1365E+03 |
| 650 | 7.4200E-03 | 5.0900E+01 | 1.1800E-02 | 5.0919E+01 | 1.0693E+03 |
| 700 | 7.3300E-03 | 4.8000E+01 | 1.1600E-02 | 4.8019E+01 | 1.0084E+03 |
| 750 | 7.2700E-03 | 4.5300E+01 | 1.1500E-02 | 4.5319E+01 | 9.5169E+02 |
| 800 | 7.2200E-03 | 4.2900E+01 | 1.1500E-02 | 4.2919E+01 | 9.0129E+02 |
| 850 | 7.1800E-03 | 4.0700E+01 | 1.1500E-02 | 4.0719E+01 | 8.5509E+02 |
| 900 | 7.1500E-03 | 3.8700E+01 | 1.1500E-02 | 3.8719E+01 | 8.1309E+02 |
| 950 | 7.1300E-03 | 3.6800E+01 | 1.1400E-02 | 3.6819E+01 | 7.7319E+02 |
| 1000 | 7.1100E-03 | 3.5100E+01 | 1.1400E-02 | 3.5119E+01 | 7.3749E+02 |
| 1500 | 6.9600E-03 | 2.3600E+01 | 1.1400E-02 | 2.3618E+01 | 4.9599E+02 |
| 2000 | 6.8400E-03 | 1.8100E+01 | 1.1400E-02 | 1.8118E+01 | 3.8048E+02 |
| 2500 | 6.7200E-03 | 1.5400E+01 | 1.1300E-02 | 1.5418E+01 | 3.2378E+02 |
| 3000 | 6.6100E-03 | 1.4000E+01 | 1.1300E-02 | 1.4018E+01 | 2.9438E+02 |
| 3500 | 6.5000E-03 | 1.3100E+01 | 1.1300E-02 | 1.3118E+01 | 2.7547E+02 |
| 4000 | 6.3800E-03 | 1.2400E+01 | 1.1200E-02 | 1.2418E+01 | 2.6077E+02 |
| 4500 | 6.2700E-03 | 1.1900E+01 | 1.1200E-02 | 1.1917E+01 | 2.5027E+02 |
| 5000 | 6.1700E-03 | 1.1400E+01 | 1.1200E-02 | 1.1417E+01 | 2.3976E+02 |
| 5500 | 6.0600E-03 | 1.1000E+01 | 1.1100E-02 | 1.1017E+01 | 2.3136E+02 |
| 6000 | 5.9600E-03 | 1.0700E+01 | 1.1100E-02 | 1.0717E+01 | 2.2506E+02 |
| 6500 | 5.8600E-03 | 1.0300E+01 | 1.1100E-02 | 1.0317E+01 | 2.1666E+02 |
| 7000 | 5.7600E-03 | 9.9600E+00 | 1.1100E-02 | 9.9769E+00 | 2.0951E+02 |
| 7500 | 5.6600E-03 | 9.6300E+00 | 1.1000E-02 | 9.6467E+00 | 2.0258E+02 |
| 8000 | 5.5600E-03 | 9.3200E+00 | 1.1000E-02 | 9.3366E+00 | 1.9607E+02 |
| 8500 | 5.4700E-03 | 9.0200E+00 | 1.1000E-02 | 9.0365E+00 | 1.8977E+02 |
| 9000 | 5.3800E-03 | 8.7400E+00 | 1.0900E-02 | 8.7563E+00 | 1.8388E+02 |

| | | | | | |
|---|---|---|---|---|---|
| 9500 | 5.2800E-03 | 8.4700E+00 | 1.0900E-02 | 8.4862E+00 | 1.7821E+02 |
| 10000 | 5.1900E-03 | 8.2100E+00 | 1.0900E-02 | 8.2261E+00 | 1.7275E+02 |
| 15000 | 4.3800E-03 | 6.1300E+00 | 1.0600E-02 | 6.1450E+00 | 1.2904E+02 |
| 20000 | 3.7000E-03 | 4.7500E+00 | 1.0300E-02 | 4.7640E+00 | 1.0004E+02 |
| 25000 | 3.1300E-03 | 3.8000E+00 | 1.0100E-02 | 3.8132E+00 | 8.0078E+01 |
| 30000 | 2.6500E-03 | 3.1200E+00 | 9.8100E-03 | 3.1325E+00 | 6.5782E+01 |
| 35000 | 2.2400E-03 | 2.6200E+00 | 9.5600E-03 | 2.6318E+00 | 5.5268E+01 |
| 40000 | 1.9000E-03 | 2.2400E+00 | 9.3200E-03 | 2.2512E+00 | 4.7276E+01 |
| 45000 | 1.6100E-03 | 1.9400E+00 | 9.0800E-03 | 1.9507E+00 | 4.0964E+01 |
| 50000 | 1.3700E-03 | 1.7000E+00 | 8.8500E-03 | 1.7102E+00 | 3.5915E+01 |
| 55000 | 1.1600E-03 | 1.5000E+00 | 8.6300E-03 | 1.5098E+00 | 3.1706E+01 |
| 60000 | 9.9200E-04 | 1.3400E+00 | 8.4100E-03 | 1.3494E+00 | 2.8337E+01 |
| 65000 | 8.4600E-04 | 1.2000E+00 | 8.2000E-03 | 1.2090E+00 | 2.5390E+01 |
| 70000 | 7.2200E-04 | 1.0900E+00 | 8.0000E-03 | 1.0987E+00 | 2.3073E+01 |
| 75000 | 6.1800E-04 | 9.8800E-01 | 7.8000E-03 | 9.9642E-01 | 2.0925E+01 |
| 80000 | 5.3000E-04 | 9.0400E-01 | 7.6100E-03 | 9.1214E-01 | 1.9155E+01 |
| 85000 | 4.5500E-04 | 8.3200E-01 | 7.4300E-03 | 8.3989E-01 | 1.7638E+01 |
| 90000 | 3.9200E-04 | 7.7100E-01 | 7.2500E-03 | 7.7864E-01 | 1.6351E+01 |
| 95000 | 3.3900E-04 | 7.1900E-01 | 7.0700E-03 | 7.2641E-01 | 1.5255E+01 |
| 100000 | 2.9400E-04 | 6.7400E-01 | 6.9000E-03 | 6.8119E-01 | 1.4305E+01 |
| 150000 | 9.0900E-05 | 4.7000E-01 | 5.4300E-03 | 4.7552E-01 | 9.9859E+00 |
| 200000 | 4.8600E-05 | 4.2800E-01 | 4.3300E-03 | 4.3238E-01 | 9.0800E+00 |
| 250000 | 3.7100E-05 | 4.1700E-01 | 3.4800E-03 | 4.2052E-01 | 8.8309E+00 |
| 300000 | 3.2400E-05 | 4.0800E-01 | 2.8300E-03 | 4.1086E-01 | 8.6281E+00 |
| 350000 | 2.9600E-05 | 3.9700E-01 | 2.3300E-03 | 3.9936E-01 | 8.3866E+00 |
| 400000 | 2.7600E-05 | 3.8400E-01 | 1.9400E-03 | 3.8597E-01 | 8.1053E+00 |
| 450000 | 2.6000E-05 | 3.7000E-01 | 1.6300E-03 | 3.7166E-01 | 7.8048E+00 |
| 500000 | 2.4700E-05 | 3.5600E-01 | 1.3800E-03 | 3.5740E-01 | 7.5055E+00 |
| 550000 | 2.3700E-05 | 3.4200E-01 | 1.1800E-03 | 3.4320E-01 | 7.2073E+00 |
| 600000 | 2.2800E-05 | 3.2900E-01 | 1.0200E-03 | 3.3004E-01 | 6.9309E+00 |
| 650000 | 2.1900E-05 | 3.1700E-01 | 8.9000E-04 | 3.1791E-01 | 6.6761E+00 |
| 700000 | 2.1200E-05 | 3.0500E-01 | 7.8200E-04 | 3.0580E-01 | 6.4219E+00 |
| 750000 | 2.0500E-05 | 2.9500E-01 | 6.9300E-04 | 2.9571E-01 | 6.2100E+00 |
| 800000 | 1.9900E-05 | 2.8500E-01 | 6.1900E-04 | 2.8564E-01 | 5.9984E+00 |
| 850000 | 1.9300E-05 | 2.7600E-01 | 5.5700E-04 | 2.7658E-01 | 5.8081E+00 |
| 900000 | 1.8700E-05 | 2.6700E-01 | 5.0400E-04 | 2.6752E-01 | 5.6180E+00 |
| 950000 | 1.8200E-05 | 2.6000E-01 | 4.6000E-04 | 2.6048E-01 | 5.4700E+00 |
| 1000000 | 1.7700E-05 | 2.5300E-01 | 4.2200E-04 | 2.5344E-01 | 5.3222E+00 |

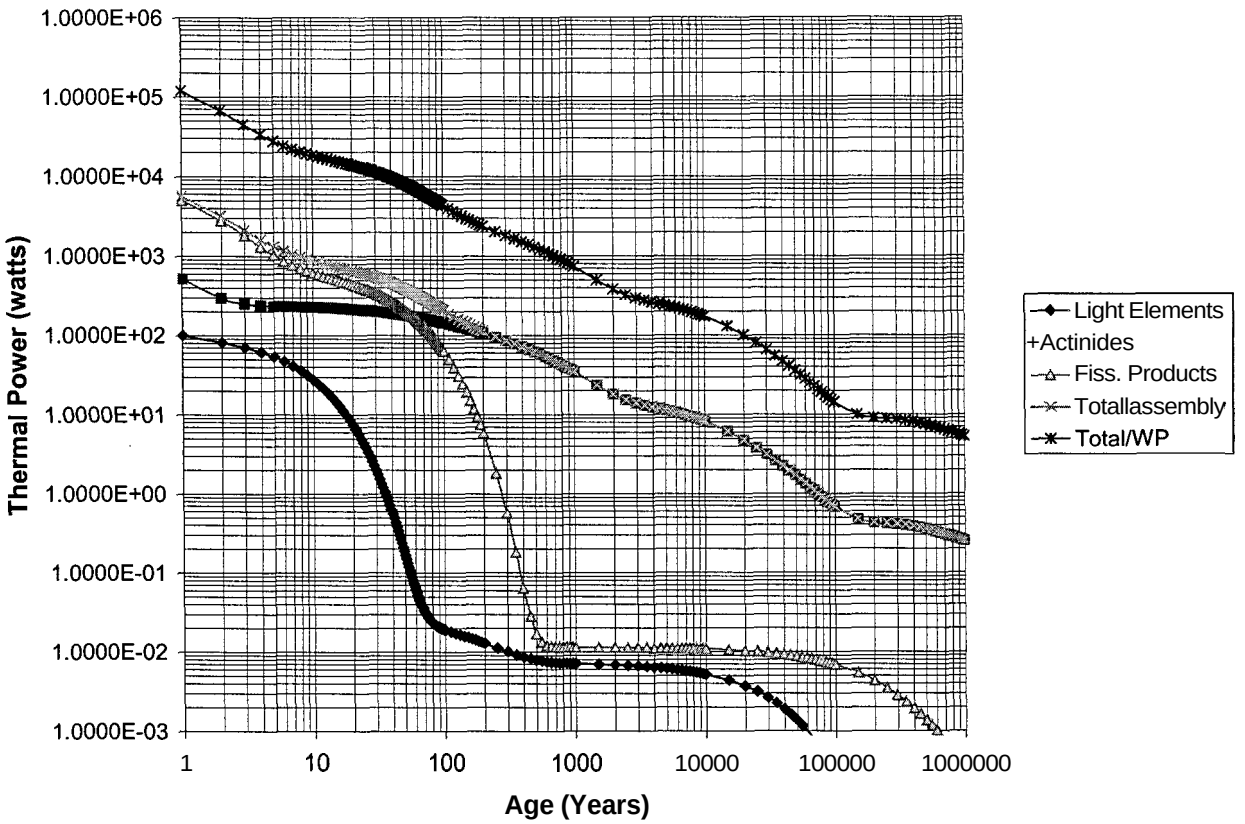



Figure 6. Thermal Power of the Average PWR SNF Assembly

Originator: JST Date: 9/13/02 Checker: GR Date: 9/16/02

# 7. REFERENCES

## 7.1 DOCUMENTS CITED

ASM International 1990. *Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, Specific Metals and Alloys.* Volume 2 of *Metals Handbook.* 10th Edition. Page 666. [Meterials Park, Ohio]: American Society for Metals. TIC: 239807.

Briesmeister, J.F., ed. 1997. *MCNP-A General Monte Carlo N-Particle Transport Code.* LA-12625-M, Version 4B. Los Alamos, New Mexico: Los Alamos National Laboratory. ACC: MOL.19980624.0328.

BSC (Bechtel SAIC Company) 2001. *Dose Rate Calculation for the 21-PWR UCF Waste Package.* CAL-UDC-NU-000002 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010627.0027.

CRWMS M&O 1997. *Waste Container Cavity Size Determination.* BBAA00000-01717-0200-00026 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980106.0061.

CRWMS M&O 1998a. *Software Code: MCNP.* 4B2LV. HP: 30033 V4B2LV.

CRWMS M&O 1998b. *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code.* CSCI: 30033 V4B2LV. DI: 30033-2003, Rev. 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980622.0637.

CRWMS M&O 1999a. *Classification of the MGR Uncanistered Spent Nuclear Fuel Disposal Container System.* ANL-UDC-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0216.

CRWMS M&O 1999b. *PWR Source Term Generation and Evaluation.* BBAC00000-01717-0210-00010 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000113.0333.

CRWMS M&O 1999c. *Output Files for PWR Source Term Generation and Evaluation.* BBAC00000-01717-0210-00010 *REV* 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991111.0702.

DOE (U.S. Department of Energy) 2002. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 12. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020819.0387.

Harmon, C.D., II; Busch, R.D.; Briesmeister, J.F.; and Forster, R.A. 1994. *Criticality Calculations with MCNP™: A Primer.* LA-12827-M. Los Alamos, New Mexico: Los Alamos National Laboratory. TIC: 234014.

Parrington, J.R.; Knox, H.D.; Breneman, S.L.; Baum, E.M.; and Feiner, F. 1996. *Nuclides and*

*Isotopes, Chart of the Nuclides.* 15th Edition. San Jose, California: General Electric Company and KAPL, Inc. TIC: 233705.

Punatar, M.K. 2001. *Summary Report of Commercial Reactor Criticality Data for Crystal River Unit 3.* TDR-UDC-NU-000001 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010702.0087.

Reed, D.T. and Van Konynenburg, R.A. 1988. "Effect of Ionizing Radiation on Moist Air Systems." *Scientific Basis for Nuclear Waste Management XI, Symposium held November 30-December 3, 1987, Boston, Massachusetts.* Apted, M.J. and Westerman, 'R.E., eds. 112, 393-404. Pittsburgh, Pennsylvania: Materials Research Society. TIC: 203662.

Reed, D.T. and Van Konynenburg, R.A. 1991. "Effect of Ionizing Radiation on the Waste Package Environment." *High Level Radioactive Waste Management, Proceedings of the Second Annual International Conference, Las Vegas, Nevada, April 28-May 3, 1991.* 2,1396-1403. La Grange Park, Illinois: American Nuclear Society. TIC: 204272.

Weast, R.C. and Astle, M.J., eds. 1979. *CRC Handbook of Chemistry and Physics.* 60th Edition. 2nd Printing 1980. Boca Raton, Florida: CRC Press. TIC: 245312.

## 7.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

ANSI/ANS-6.1.1-1977. *Neutron and Gamma-Ray Flux-to-Dose-Rate Factors.* La Grange Park, Illinois: American Nuclear Society. TIC: 239401.

AP-3.12Q, Rev. 1, ICN 2. *Design Calculations and Analyses.* Washington, D.C.: *U.S.* Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020607.0013.

AP-SI.1Q, Rev. 3, ICN 4. *Software Management.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020520.0283.

ASME (American Society of Mechanical Engineers) 1993. *Steam Tables, Thermodynamic and Transport Properties of Steam.* 6th Edition. New York, New York: American Society of Mechanical Engineers. TIC: 103243.

ASTM G 1-90 (Reapproved 1999). 1999. *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 238771.

ASTM B 811-90. 1991. *Standard Speczfzcation for Wrought Zirconium Alloy Seamless Tubes for Nuclear Reactor Fuel Cladding.* Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 239780.

ASTM A 240/A 240M-97a. 1997. *Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 239431.

ASTM B 575-97. 1998. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241816.

## 8. ATTACHMENTS

The list of attachments is presented in Table 24. Electronic output files are provided on a compact disk that is Attachment III of this calculation. The files' attributes of the output files are listed in Table 25. Each file is identified by its name, size (in bytes), and the date and time. The files can be read using Word-Pad application in Microsoft Windows Explorer. It should be noted that the date and time reflect the time of transfer from the HP to the personal computer. The actual date and time of each run completion can be found in its corresponding file.

Table 24. List of Attachments

| Description | Attachment Number | No. of Pages |
|---|---|---|
| SK – 0175 REV 02<br>21-PWR Waste Package Configurations for Site Recommendation | I | 2 |
| SK – 0191 REV 00<br>21-PWR Waste Package Weld Configuration | II | 1 |
| Compact Disk of MCNP Output and Excel Files | III | N/A |

Table 25. Files in the Compact Disk

| File Name | Description | Size (bytes) | Date | Time |
|---|---|---|---|---|
| 1g10o | MCNP gamma case at RH=40% & 90° C, 10 years SNF | 214,683 | 7/25/2002 | 10:38a |
| 1g15o | MCNP gamma case at RH=40% & 90° C, 15 years SNF | 1206,287 | 1712512002 | 10:39a |
| 1g200 | MCNP gamma case at RH=40% & 90° C, 20 years SNF | 206,153 | 712512002 | 10:39a |
| 1g25o | MCNP gamma case at RH=40% & 90" C, 25 years SNF | 206,165 | 7/25/2002 | 10:39a |
| 1g35o | MCNP gamma case at RH=40% & 90° C, 35 years SNF | 1206,165 | 7/25/2002 | 10:39a |
| 1g50o | MCNP gamma case at RH=40% & 90° C, 50 years SNF | 206,165 | 712512002 | 10:39a |
| 1g70o | MCNP gamma case at RH=40% & 90" C, 70 years SNF | 206,287 | 7/25/2002 | 10:39a |
| 1g100o | MCNP gamma case at RH=40% & 90° C. 100 vears SNF | 206,153 | 712512002 | 04:12p |
| 1g150o | MCNP gamma case at RH=40% & 90" C, 150 years SNF | 220,202 | 712512002 | 04:12p |
| 1g200o | MCNP gamma case at RH=40% & 90" C, 200 years SNF | 220,993 | 712512002 | 04:12p |
| 1g250o | MCNP gamma case at RH=40% & 90" C, 250 years SNF | 221,396 | 7/25/2002 | 04:12p |
| 1g350o | MCNP gamma case at RH=40% & 90" C, 350 years SNF | 207,084 | 712512002 | 04:13p |
| 1g500o | MCNP gamma case at RH=40% & 90" C, 500years SNF | 218,162 | 712512002 | 04:13p |
| 1g700o | MCNP gamma case at RH=40% & 90° C, 700 years SNF | 214,102 | 712512002 | 04:13p |
| l g l.0ko | MCNP gamma case at RH=40% & 90" C, 1000 years SNF | 218,426 | 712512002 | 04:11p |
| 1g1.5ko | MCNP gamma case at RH=40% & 90" C, 1500 years SNF | 205,884 | 7/25/2002 | 04:12p |
| 1g2ko | MCNP gamma case at RH=40% & 90" C. 2000 vears SNF | 207,884 | 712512002 | 04:12p |
| 1g2.5ko | MCNP gamma case at RH=40% & 90° C, 2500 years SNF | 1208,684 | 7/25/2002 | 04:12p |
| 1g3.5ko | MCNP gamma case at RH=40% & 90° C, 3500 years SNF | 207,084 | 7/25/2002 | 04:12p |
| ▮g5ko | MCNP gamma case at RH=40% & 90° C, 5000 years SNF | 207,472 | 712512002 | 04:13p |
| 1g7ko | MCNP gamma case at RH=40% & 90° C, 7000 years SNF | 207,472 | 712512002 | 04:13p |
| 1g10ko | MCNP gamma case at RH=40% & 90" C, 10000 years SNF | 208,284 | 7/25/2002 | 04:12p |
| 1g15ko | MCNP gamma case at RH=40% & 90° C, 15000 years SNF | 219,635 | 712512002 | 04:12p |
| ▮g20ko | MCNP gamma case at RH=40% & 90" C, 20000 years SNF | 214,790 | 7/25/2002 | 04:12p |
| 1g25ko | MCNP gamma case at RH=40% & 90° C, 25000 vears SNF | 208,205 | 712512002 | 04:12p |
| 1g35ko | MCNP gamma case at RH=40% & 90° C, 35000 years SNF | 1209.500 | 17/25/2002 | 10:37a |
| 1g50ko | MCNP gamma case at RH=40% & 90" C, 50000 years SNF | 1222,310 | 7/25/2002 | 04:13p |

Originator: JoT Date: 9/16/02 Checker: GR Date: 9/16/02

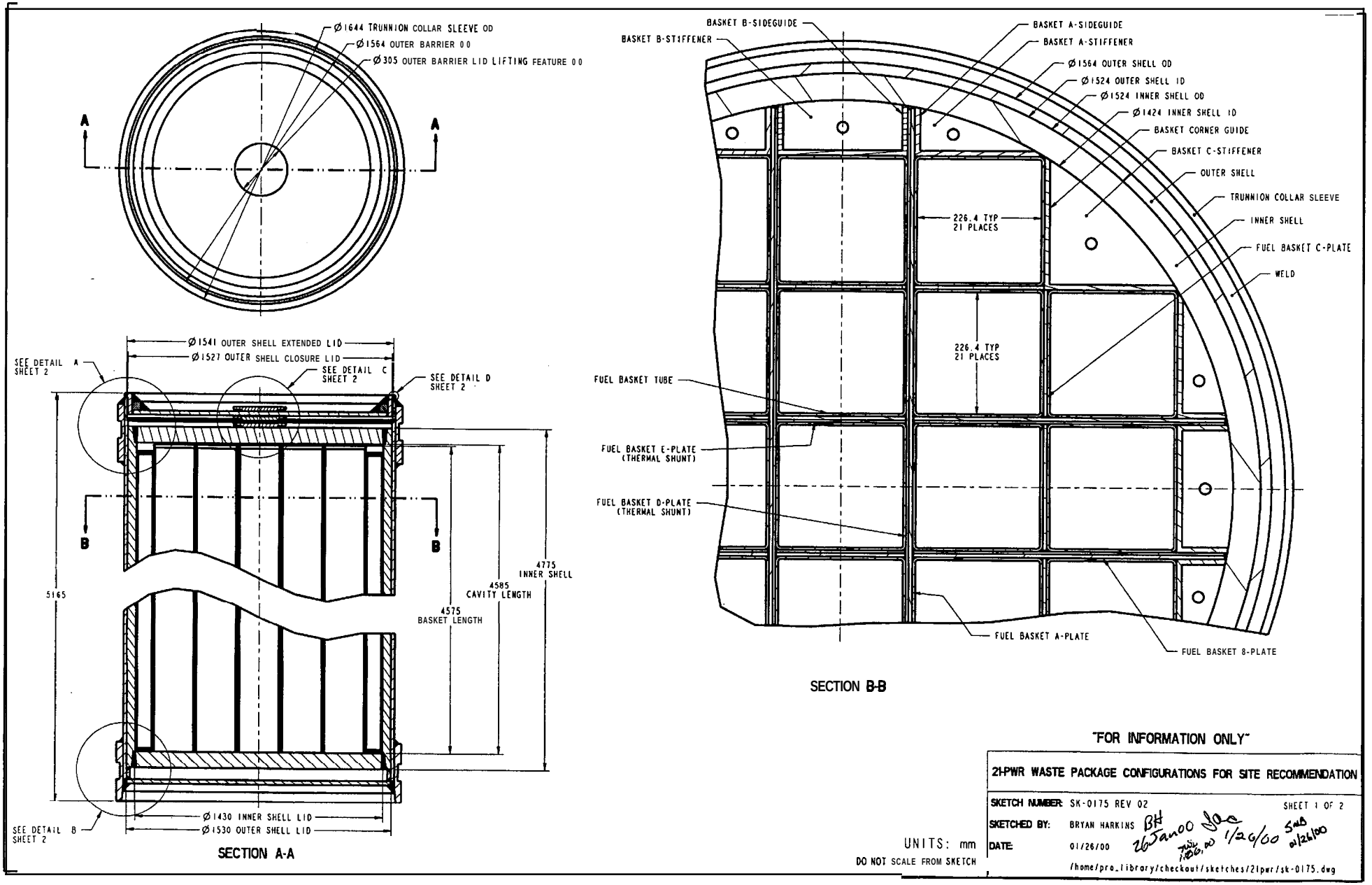
| | | | | |
|---|---|---|---|---|
| 1g70ko | MCNP gamma case at RH=40% & 90° C, 70000 years SNF | 1208.309 | 17/25/2002 | 04:13p |
| 1g100ko | MCNP gamma case at RH=40% & 90° C. 100000 vears SNF | 205,918 | 7/25/2002 | 04:12p |
| 1g150ko | MCNP gamma case at RH=40% & 90" C, 150000 years SNF | 208,855 | 7/25/2002 | 04:12p |
| 1g200ko | MCNP gamma case at RH=40% & 90" C, 200000 years SNF | 208,855 | 7/25/2002 | 04:12p |
| 1g250ko | MCNP gamma case at RH=40% & 90" C, 250000 years SNF | 208.966 | 7/25/2002 | 04:12p |
| 1g350ko | MCNP gamma case at RH=40% & 90° C, 350000 years SNF | 1208,309 | 17/25/2002 | 04:13p |
| 1g500ko | MCNP gamma case at RH=40% & 90° C, 500000 years SNF | 205,650 | 7/25/2002 | 04:13p |
| 1g700ko | MCNP gamma case at RH=40% & 90" C, 700000 years SNF | 208,954 | 7/25/2002 | 04:13p |
| 1g1mo | MCNP gamma case at RH=40% & 90° C, 1000000 years SNF | 208,420 | 7/25/2002 | 04:12p |
| 2g10o | MCNP gamma case at RH=40% & 30° C, 10 years SNF | 208,879 | 7/25/2002 | 10:38a |
| 2g15o | MCNP gamma case at RH=40% & 30" C, 15 years SNF | 220,311 | 7/25/2002 | 10:38a |
| 2g20o | MCNP gamma case at RH=40% & 30" C, 20 years SNF | 220,980 | 7/25/2002 | 10:38a |
| 2g25o | MCNP gamma case at RH=40% & 30° C, 25 years SNF | 214,517 | 7/25/2002 | 10:38a |
| 2g35o | MCNP gamma case at RH=40% & 30° C, 35 years SNF | 221,247 | 7/25/2002 | 10:38a |
| 2g50o | MCNP gamma case at RH=40% & 30° C, 50 years SNF | 208,855 | 7/25/2002 | 10:38a |
| 2g70o | MCNP gamma case at RH=40% & 30° C, 70 years SNF | 208,855 | 7/25/2002 | 10:38a |
| 2g100o | MCNP gamma case at RH=40% & 30° C, 100 years SNF | 208,855 | 7/25/2002 | 04:09p |
| 2g150o | MCNP gamma case at RH=40% & 30° C, 150 years SNF | 220,202 | 7/25/2002 | 04:09p |
| 2g200o | MCNP gamma case at RH=40% & 30° C, 200 years SNF | 220.993 | 7/25/2002 | 04:09p |
| 2g250o | MCNP gamma case at RH=40% & 30° C, 250 years SNF | 1221,396 | 17/25/2002 | 04:1Op |
| 2g350o | MCNP gamma case at RH=40% & 30° C, 350 years SNF | 207,084 | 7/25/2002 | 04:1Op |
| 2g500o | MCNP gamma case at RH=40% & 30" C, 500years SNF | 218,162 | 7/25/2002 | 04:1Op |
| 2g700o | MCNP gamma case at RH=40% & 30" C. 700 years SNF | 220,164 | 712512002 | 04:11p |
| 2g1.0ko | MCNP gamma case at RH=40% & 30" C, 1000 years SNF | 218,426 | 7/25/2002 | 04:08p |
| 2g1.5ko | MCNP gamma case at RH=40% & 30" C, 1500 years SNF | 205,884 | 7/25/2002 | 04:08p |
| 2g2ko | MCNP gamma case at RH=40% & 30° C, 2000 years SNF | 207.884 | 712512002 | 04:10p |
| 2g2.5ko | MCNP gamma case at RH=40% & 30° C, 2500 years SNF | 208,684 | 7/25/2002 | 04:09p |
| 2g3.5ko | MCNP gamma case at RH=40% & 30° C, 3500 years SNF | 207,084 | 7/25/2002 | 04:1Op |
| 2g5ko | MCNP gamma case at RH=40% & 30" C, 5000 years SNF | 207.472 | 7/25/2002 | 04:10p |
| 2g7ko | MCNP gamma case at RH=40% & 30° C, 7000 years SNF | 207,484 | 7/25/2002 | 04:11p |
| 2g10ko | MCNP gamma case at RH=40% & 30" C, 10000 years SNF | 208,284 | 7/25/2002 | 04:09p |
| 2g15ko | MCNP gamma case at RH=40% & 30° C, 15000 years SNF | 219,635 | 7/25/2002 | 04:09p |
| 2g20ko | MCNP gamma case at RH=40% & 30" C, 20000 years SNF | 214,790 | 7/25/2002 | 04:10p |
| 2g25ko | MCNP gamma case at RH=40% & 30° C, 25000 years SNF | 208,205 | 7/25/2002 | 04:10p |
| 2g35ko | MCNP gamma case at RH=40% & 30" C, 35000 years SNF | 209,500 | 7/25/2002 | 10:37a |
| 2g50ko | MCNP gamma case at RH=40% & 30° C, 50000 years SNF | 222,310 | 712512002 | 04:10p |
| 2g70ko | MCNP gamma case at RH=40% & 30° C, 70000 years SNF | 208,309 | 7/25/2002 | 04:11p |
| 2g100ko | MCNP gamma case at RH=40% & 30° C, 100000 years SNF | 205,930 | 7/25/2002 | 04:09p |
| 2g150ko | MCNP gamma case at RH=40% & 30° C, 150000 years SNF | 208,855 | 7/25/2002 | 04:09p |
| 2g200ko | MCNP gamma case at RH=40% & 30" C, 200000 years SNF | 208,855 | 7/25/2002 | 04:09p |
| 2g250ko | MCNP gamma case at RH=40% & 30° C, 250000 years SNF | 208,966 | 7/25/2002 | 04:10p |
| 2g350ko | MCNP gamma case at RH=40% & 30" C, 350000 years SNF | 208.309 | 7/25/2002 | 04:10p |
| 2g500ko | MCNP gamma case at RH=40% & 30° C, 500000 years SNF | 205,650 | 712512002 | 04:1Op |
| 2g700ko | MCNP gamma case at RH=40% & 30" C, 700000 years SNF | 208,954 | 712512002 | 04:11p |
| 2g1mo | MCNP gamma case at RH=40% & 30° C, 1000000 years SNF | 208.420 | 7/25/2002 | 04:09p |
| 3g10o | MCNP gamma case at RH=90% & 30° C, 10 years SNF | 208,879 | 17/25/2002 | 10:39a |
| 3g15o | MCNP gamma case at RH=90% & 30° C, 15 years SNF | 214,517 | 7/25/2002 | 10:39a |
| 3g20o | MCNP gamma case at RH=90% & 30° C, 20 years SNF | 208,588 | 7/25/2002 | 10:40a |

| | | | | |
|---|---|---|---|---|
| 3g25o | MCNP gamma case at RH=90% & 30° C, 25 years SNF | 214,517 | 7/25/2002 | 10:40a |
| 3g35o | MCNP gamma case at RH=90% & 30" C, 35 years SNF | 221,247 | 7/25/2002 | 10:40a |
| 3g50o | MCNP gamma case at RH=90% & 30" C, 50 years SNF | 208,855 | 7/25/2002 | 10:40a |
| 3g70o | MCNP gamma case at RH=90% & 30° C, 70 years SNF | 1208,855 | 17/25/2002 | 10:40a |
| 3g100o | MCNP gamma case at RH=90% & 30° C, 100 years SNF | 208,855 | 7/25/2002 | 04:19p |
| 3g150o | MCNP gamma case at RH=90% & 30° C, 150 years SNF | 220,202 | 7/25/2002 | 04:21p |
| 3g200o | MCNP gamma case at RH=90% & 30" C. 200 years SNF | 220,993 | 7/25/2002 | 04:21P |
| 3g250o | MCNP gamma case at RH=90% & 30° C, 250 years SNF | 1221,396 | 17/25/2002 | 04:21p |
| 3g350o | MCNP gamma case at RH=90% & 30° C, 350 years SNF | 207,084 | 7/25/2002 | 04:22p |
| 3g500o | MCNP gamma case at RH=90% & 30° C, 500years SNF | 218,162 | 7/25/2002 | 04:22p |
| 3g700o | MCNP gamma case at RH=90% & 30" C, 700 years SNF | 214,102 | 7/25/2002 | 04:22p |
| 3g1.0ko | MCNP gamma case at RH=90% & 30° C, 1000 years SNF | 218,426 | 7/25/2002 | 04:14p |
| 3g1.5ko | MCNP gamma case at RH=90% & 30° C, 1500 years SNF | 205,884 | 7/25/2002 | 04:14p |
| 3g2ko | MCNP gamma case at RH=90% & 30° C, 2000 years SNF | 207,884 | 7/25/2002 | 04:22p |
| 3g2.5ko | MCNP gamma case at RH=90% & 30° C, 2500 years SNF | 208,684 | 7/25/2002 | 04:21P |
| 3g3.5ko | MCNP gamma case at RH=90% & 30" C, 3500 years SNF | 207,084 | 7/25/2002 | 04:22p |
| 3g5ko | MCNP gamma case at RH=90% & 30° C, 5000 years SNF | 207,472 | 712512002 | 04:22p |
| 3g7ko | MCNP gamma case at RH=90% & 30" C. 7000 vears SNF | 207,472 | 7/25/2002 | 04:23p |
| 3g10ko | MCNP gamma case at RH=90% & 30" C, 10000 years SNF | 208,284 | 7/25/2002 | 04:21p |
| 3g15ko | MCNP gamma case at RH=90% & 30° C, 15000 years SNF | 219,635 | 712512002 | 04:21p |
| 3g20ko | MCNP gamma case at RH=90% & 30" C, 20000 years SNF | 214,790 | 7/25/2002 | 04:21p |
| 3g25ko | MCNP gamma case at RH=90% & 30" C, 25000 years SNF | 208,205 | 7/25/2002 | 04:22p |
| 3g35ko | MCNP gamma case at RH=90% & 30" C, 35000 years SNF | 209,500 | 7/25/2002 | 10:37a |
| 3g50ko | MCNP gamma case at RH=90% & 30" C, 50000 years SNF | 222,310 | 7/25/2002 | 04:22p |
| 3g70ko | MCNP gamma case at RH=90% & 30° C. 70000 vears SNF | 208,309 | 7/25/2002 | 04:23p |
| 3g100ko | MCNP gamma case at RH=90% & 30° C, 100000 years SNF | 205,918 | 7/25/2002 | 04:19p |
| 3g150ko | MCNP gamma case at RH=90% & 30" C, 150000 years SNF | 208,855 | 7/25/2002 | 04:21p |
| 3g200ko | MCNP gamma case at RH=90% & 30° C, 200000 years SNF | 208,855 | 7/25/2002 | 04:21D |
| 3g250ko | MCNP gamma case at RH=90% & 30" C. 250000 vears SNF | 208,966 | 7/25/2002 | 04:21p |
| 3g350ko | MCNP gamma case at RH=90% & 30° C, 350000 years SNF | 1208,309 | 7/25/2002 | 04:22p |
| 3g500ko | MCNP gamma case at RH=90% & 30° C, 500000 years SNF | 1205,650 | 7/25/2002 | 04:22p |
| 3g700ko | MCNP gamma case at RH=90% & 30" C, 700000 years SNF | 1208,954 | 7/25/2002 | 04:22p |
| 3g1mo | MCNP gamma case at RH=90% & 30° C, 1000000 years SNF | 208,420 | 7/25/2002 | 04:21p |
| 4g10o | MCNP gamma case at RH=90% & 90° C, 10 years SNF | 208,879 | 9/12/2002 | 07:45a |
| 4g15o | MCNP gamma case at RH=90% & 90" C, 15 years SNF | 208,321 | 9/12/2002 | 07:46a |
| 4g20o | MCNP gamma case at RH=90% & 90" C, 20 years SNF | (208,588 | 19/12/2002 | 07:46a |
| 4g25o | MCNP gamma case at RH=90% & 90" C, 25 years SNF | 214,517 | 9/12/2002 | 07:46a |
| 4g35o | MCNP gamma case at RH=90% & 90" C, 35 years SNF | 221,247 | 9/12/2002 | 07:47a |
| 4g50o | MCNP gamma case at RH=90% & 90" C, 50 years SNF | 208,855 | 9/12/2002 | 07:47a |
| 4g70o | MCNP gamma case at RH=90% & 90" C, 70 years SNF | 208,855 | 9/12/2002 | 07:47a |
| 4g100o | MCNP gamma case at RH=90% & 90° C, 100 years SNF | 208,855 | 9/12/2002 | 07:45a |
| 4g150o | MCNP gamma case at RH=90% & 90° C, 150 years SNF | 220,202 | 9/12/2002 | 07:46a |
| 4g200o | MCNP gamma case at RH=90% & 90" C, 200 years SNF | 220,859 | 9/1212002 | 07:46a |
| 4g250o | MCNP gamma case at RH=90% & 90" C, 250 years SNF | 221,262 | 9/12/2002 | 07:46a |
| 4g350o | MCNP gamma case at RH=90% & 90" C, 350 years SNF | 207,096 | 9/12/2002 | 07:47a |
| 4g500o | MCNP gamma case at RH=90% & 90" C, 500years SNF | 218,162 | 9/12/2002 | 07:47a |
| 4g700o | MCNP gamma case at RH=90% & 90° C, 700 years SNF | 220,164 | 9/12/2002 | 07:47a |
| 4g1.0ko | MCNP gamma case at RH=90% & 90" C, 1000 years SNF | 218,426 | 9/12/2002 | 07:45a |

Originator: JST Date: 9/16/02 Checker: GR Date: 9/16/02

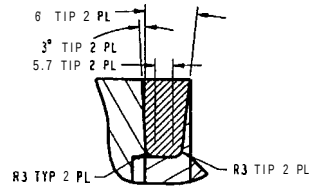
| | | | | |
|---|---|---|---|---|
| 4g1.5ko | MCNP gamma case at RH=90% & 90° C, 1500 years SNF | 1205,884 | 9/12/2002 | 07:45a |
| 4g2ko | MCNP gamma case at RH=90% & 90° C. 2000 vears SNF | 1207,884 | 19/12/2002 | 07:46a |
| 4g2.5ko | MCNP gamma case at RH=90% & 90" C, 2500 years SNF | 208,672 | 9/12/2002 | 07:46a |
| 4g3.5ko | MCNP gamma case at RH=90% & 90" C, 3500 years SNF | 207,084 | 9/1212002 | 07:47a |
| 4g5ko | MCNP gamma case at RH=90% & 90° C, 5000 years SNF | 207,472 | 9/12/2002 | 07:47a |
| 4g7ko | MCNP gamma case at RH=90% & 90° C, 7000 years SNF | 207,484 | 9/1212002 | 07:48a |
| 4g10ko | MCNP gamma case at RH=90% & 90" C. 10000 vears SNF | 208,284 | 911212002 | 07:45a |
| 4g15ko | MCNP gamma case at RH=90% & 90" C, 15000 years SNF | 219,635 | 9/1212002 | 07:46a |
| 4g20ko | MCNP gamma case at RH=90% & 90° C, 20000 years SNF | 214,924 | 9/12/2002 | 07:46a |
| 4g25ko | MCNP gamma case at RH=90% & 90" C. 25000 vears SNF | 208,205 | 9/1212002 | 07:46a |
| 4g35ko | MCNP gamma case at RH=90% & 90° C, 35000 years SNF | 209,500 | 9/1212002 | 07:47a |
| 4g50ko | MCNP gamma case at RH=90% & 90" C, 50000 years SNF | 222,444 | 9/1212002 | 07:47a |
| 4g70ko | MCNP gamma case at RH=90% & 90° C. 70000 vears SNF | 208,309 | 9/1212002 | 07:47a |
| 4g100ko | MCNP gamma case at RH=90% & 90" C, 100000 years SNF | (205,930 | 9/12/2002 | 07:45a |
| 4g150ko | MCNP gamma case at RH=90% & 90° C, 150000 years SNF | 208,855 | 9/12/2002 | 07:45a |
| 4g200ko | MCNP gamma case at RH=90% & 90" C. 200000 vears SNF | 208.855 | 9/1212002 | 07:46a |
| 4g250ko | MCNP namma case at RH=90% & 90° C. 250000 vears SNF | 1208,966 | 9/12/2002 | 07:46a |
| 4g350ko | MCNP gamma case at RH=90% & 90° C, 350000 years SNF | 208,309 | 9/1212002 | 07:47a |
| 4g500ko | MCNP gamma case at RH=90% & 90" C, 500000 years SNF | 205,650 | 911212002 | 07:47a |
| 4g700ko | MCNP gamma case at RH=90% & 90" C. 700000 years SNF | 208.954 | 911212002 | 07:47a |
| 4g1mo | MCNP gamma case at RH=90% & 90" C, 1000000 vears SNF | 208,420 | 9/12/2002 | 07:46a |
| n-23.io | MCNP neutron case at RH=40% & 30" C, per neutron | 215,152 | 7/25/2002 | 04:33p |
| n-24.io | MCNP neutron case at RH=40% & 90" C, per neutron | 215,178 | 7/25/2002 | 04:33p |
| n-25.io | MCNP neutron case at RH=90% & 30" C, per neutron | 215,178 | 7/25/2002 | 04:34p |
| n-26.io | MCNP neutron case at RH=90% & 90° C, per neutron | 215,178 | 7/25/2002 | 04:34p |
| Gamma-ED2.xls | Gamma energy depositions and dose rates for 4 moist airs | 57,856 | 9/8/2002 | 08:29p |
| Neutron-ED.xls | Neutron energy depositions and dose rates for 4 moist airs | 74,752 | 9/9/2002 | 02:03p |
| G-Source-4%48gwd.xls | Gamma source spectra of a PWR SNF at 4% initial enrichment and 48 GWd/MTU to one million years | 273,920 | 9/6/2002 | 04:49p |
| N-Source-4%48gwd.xls | Neutron source spectra of a PWR SNF at 4% initial enrichment and 48 GWd/MTU to one million years | 37,888 | 8/01/2002 | 01:37p |
| DecayPower-4%48gwd.xls | Decay heat rate to one million years | 387,584 | 810312002 | 10:07a |
| JoonLee.xls | Neutron and gamma intensities to one million years | 66,048 | 7/25/2002 | 10:20a |
| MoistAirProperties.xls | Moist air properties and atom number densities | 100,864 | 9/9/2002 | 03:13p |

Originator: JST Date: 9/13/02 Checker: GR Date: 9/16/02

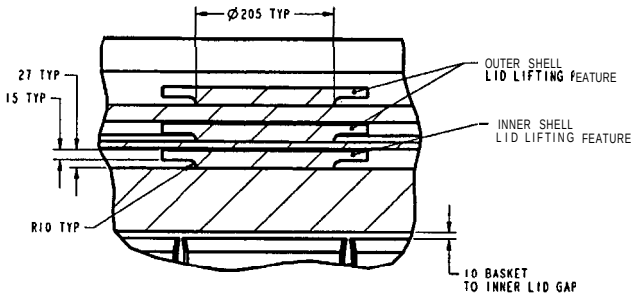



Originator: JST Date: 9/13/02

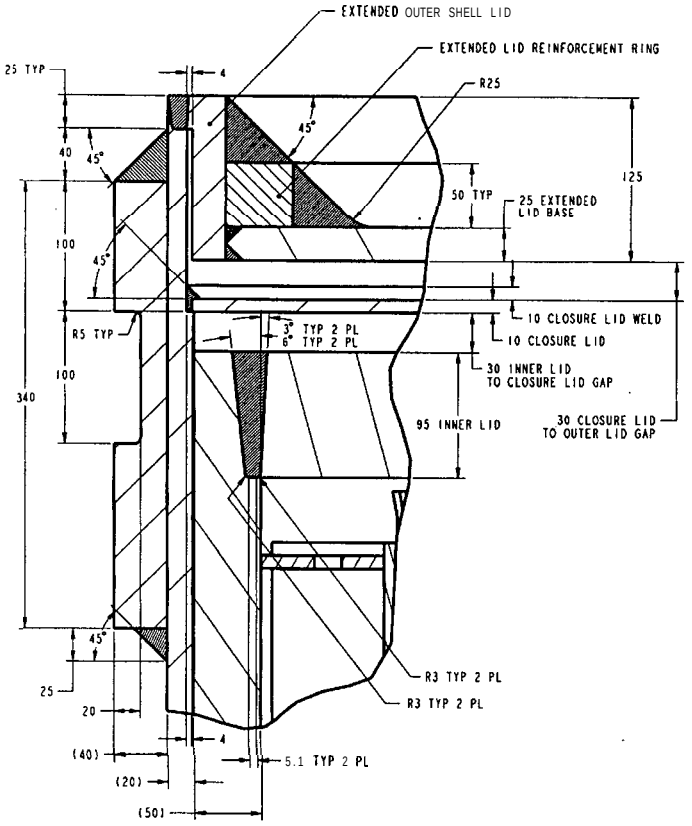
Checker: GR Date: 9/16/02




DETAIL D




DETAIL C

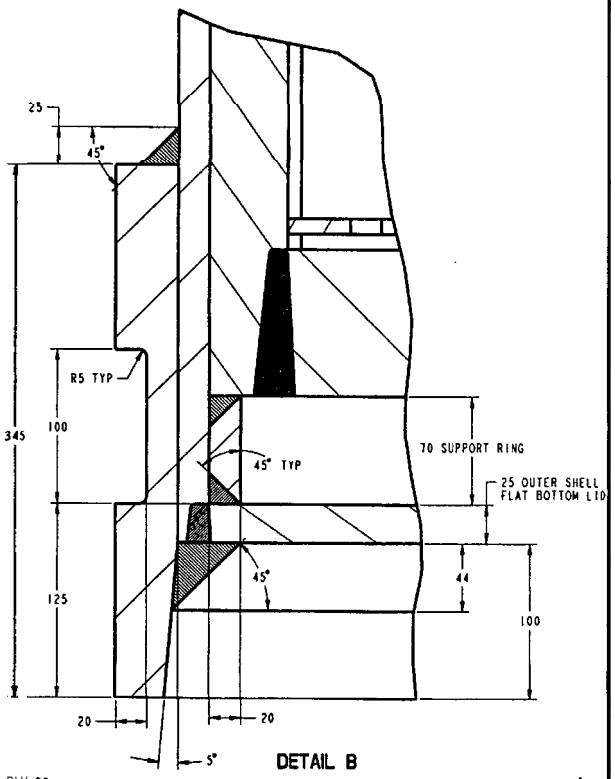



DETAIL A

21-PWR WASTE PACKAGE ASSEMBLY WITH STAINLESS STEEL/BORON PLATES

# 21-PWR CONTROL ROD WASTE PACKAGE ASSEMBLY WITH CARBOY STEEL PLATES

| COMPONENT NAME | MATERIAL | THICKNESS | MASS (KG) | QTY ROD |
|---|---|---|---|---|
| BASKET A-SIDEGUIDE | SA-516 K02700 | 10 | 27 | 32 |
| BASKET A-STIFFENER | SA-516 K02700 | 10 | 0.72 | 64 |
| BASKET B-SIDEGUIDE | SA-516 K02700 | 10 | 36 | 16 |
| BASKET B-STIFFENER | SA-516 K02700 | 10 | 1.5 | 32 |
| BASKET C-STIFFENER | SA-516 K02700 | 10 | 2.3 | 32 |
| BASKET CORNERGUIDE | SA-516 K02700 | 10 | 42 | 16 |
| FUEL BASKET A-PLATE | NEUTRONIT A 978 | 7 | 85 | 8 |
| | #SA-516 K02700 | #7 | #86 | #8 |
| FUEL BASKET B-PLATE | NEUTRONIT A 978 | 7 | 85 | 8 |
| | #SA-516 K02700 | #7 | #86 | #8 |
| FUEL BASKET C-PLATE | NEUTRONIT A 978 | 7 | 44 | 16 |
| | #SA-516 K02700 | #7 | #45 | #16 |
| FUEL BASKET D-PLATE | SB-209 A96061 T4 | 5 | 21 | 8 |
| FUEL BASKET E-PLATE | SB-209 A96061 T4 | 5 | 21 | 8 |
| FUEL BASKET TUBE | SA-516 K02700 | 5 | 164 | 21 |
| INNER SHELL | SA-240 S31600 | 50 | 8709 | 1 |
| INNER SHELL LID | SA-240 S31600 | 95 | 1200 | 2 |
| INNER LID LIFTING FEATURE | SA-240 S31600 | 27 | 12 | 1 |
| OUTER SHELL | SB-575 N06022 | 20 | 4193 | 1 |
| EXTENDED OUTER SHELL LID | SB-575 N06022 | 25 | 132 | 1 |
| EXTENDED OUTER SHELL LID BASE | SB-575 N06022 | 25 | 366 | 1 |
| OUTER LID LIFTING FEATURE | SB-575 N06022 | 27 | 13 | 2 |
| EXTENDED LID REINFORCEMENT RING | SB-575 N06022 | 50 | 97 | 1 |
| OUTER SHELL FLAT CLOSURE LID | SB-575 N06022 | 10 | 159 | 1 |
| OUTER SHELL FLAT BOTTOM LID | SB-575 N0-6022 | 25 | 396 | 1 |
| UPPER TRUNNION COLLAR SLEEVE | SB-575 N06022 | 40 | 507 | 1 |
| LOWER TRUNNION COLLAR SLEEVE | SB-575 N06022 | 40 | 497 | 1 |
| INNER SHELL SUPPORT RING | SB-575 N06022 | 20 | 41 | 1 |
| TOTAL ALLOY 22 WELDS | SFA-5.14 N06022 | - | 249 | ** |
| TOTAL 316 WELDS | SFA-5.9 S31680 | - | 128 | ** |
| WASTE PACKAGE ASSEMBLY | - | - | 26035 | 1 |
| | - | - | #26059 | #1 |
| PWR FUEL ASSEMBLY | - | - | 773.4* | 21 |
| WP ASSEMBLY WITH SNF | - | - | 42277 | 1 |
| | - | - | #42301 | #1 |




DETAIL B

# CRWMS M&O 1997. WASTE CONTAINER CAVITI SIZE DETERMINATION. BBAA00000-01717-0200-00026 RLV 00. LAS VEGAS, NV: CRWMS UAO. ACC: MOL.19980106.0061

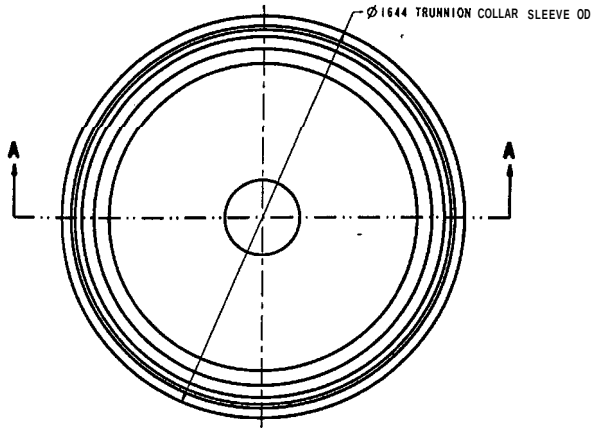
1* REFER TO SK-0191 REV 00 '21-PWR WASTE PACKAGE WELD CONFIGURATION"

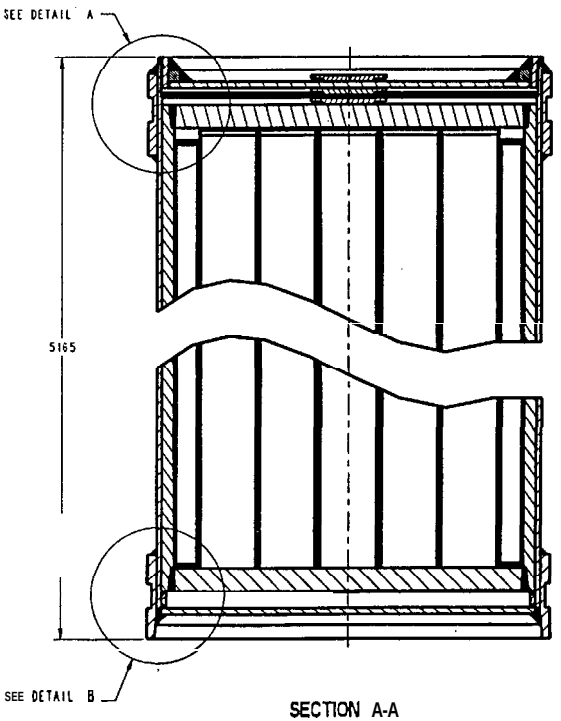
02 TMB 01/27/00

SK-0175 REV 01 | SHEET 2 OF 2

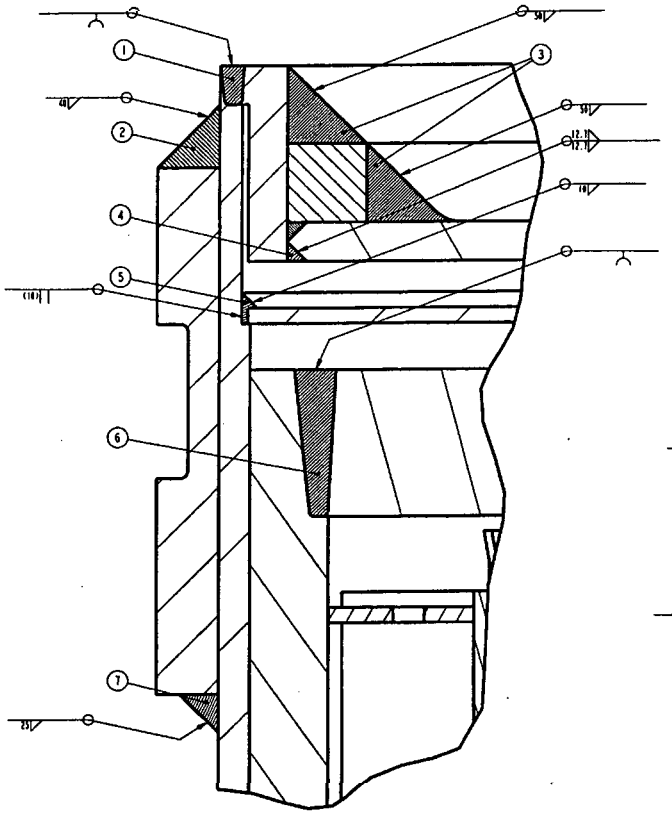
Originator: JST Date: 9/13/02

Checker: GR Date: 9/16/02

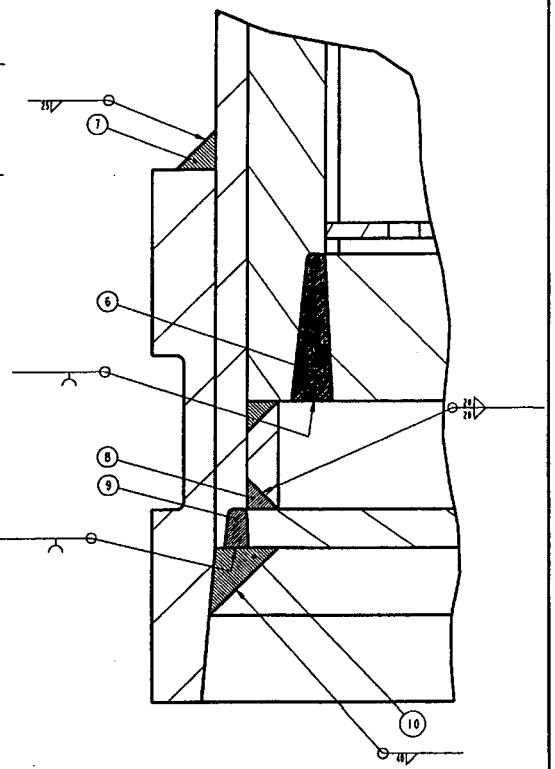



SECTION A-A




DETAIL A




DETAIL B

| WELD | MATERIAL | MASS (KG) | QTY ROD |
|---|---|---|---|
| 1 | SFA-5.14 N06022 | 14 | 1 |
| 2 | SFA-5.14 N06022 | 35 | 1 |
| 3 | SFA-5.14 N06022 | 96 | 1 |
| 4 | SFA-5.14 N06022 | 3.1 | 2 |
| 5 | SFA-5.14 N06022 | 3.8 | 1 |
| 6 | SFA-5.9 S31680 | 64 | 2 |
| 7 | SFA-5.14 N06022 | 13 | 2 |
| 8 | SFA-5.14 N06022 | 8.2 | 2 |
| 9 | SFA-5.14 N06022 | 14 | 1 |
| 10 | SFA-5.14 N06022 | 37 | 1 |
| TOTAL ALLOY 22 WELDS | SFA-5.14 N06022 | 249 | - |
| TOTAL 316 WELDS | SFA-5.9 S31680 | 128 | - |

UNITS: mm

DO NOT SCALE FROM SKETCH

| REVISIONS | | | |
|---|---|---|---|
| REV | DESCRIPTION | ORIG BY | DATE |
| 00 | ISSUED APPROVED | BA | 03/09/00 |

"FOR INFORMATION ONLY-

21-PWR WASTE PACKAGE WELD CONFIGURATION

| | |
|---|---|
| SKETCH NUMBER: | SK-0191 REV 00 |
| SKETCHED BY: | BRYAN HARKINS BA 13 March 00 |
| DATE: | 03/09/00 SMB 03/13/00 JSC 3/13/00 TGT 3/13/00 |
| FILE: | /home/pro_library/checkout/sketches/21pwr/sk-0191.dwg |

Originator: JST Date: 9/13/02

**Checker:** GR Date: 9/16/02